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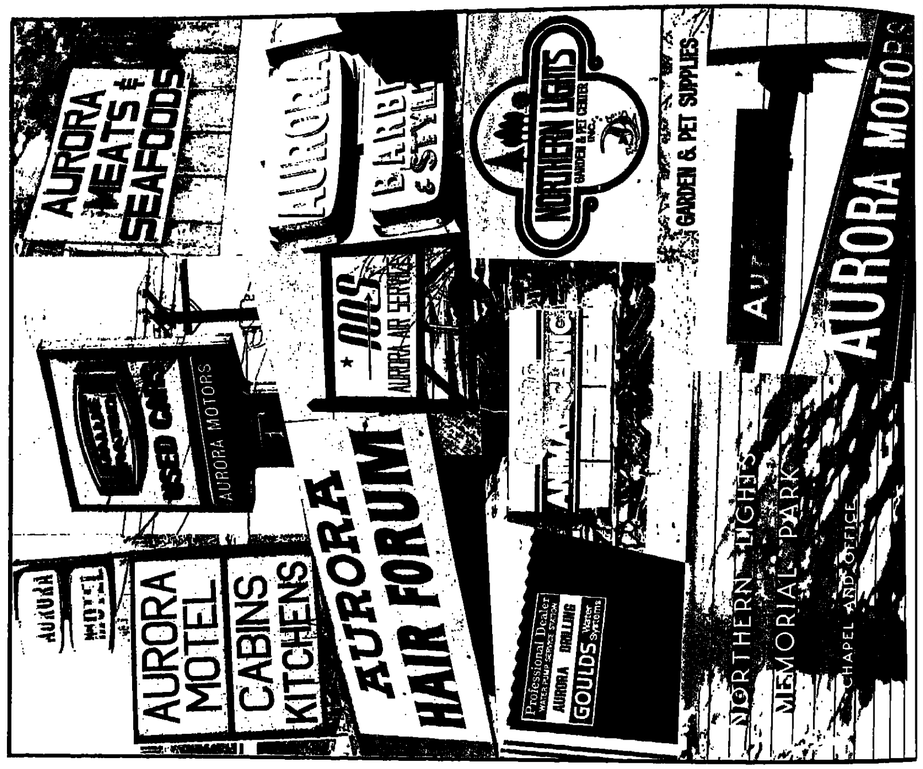

Eos, Transactions, American Geophysical Union Vol. 65, No. 15, Pages 137–144 April 10, 1984

Particles and Fields—Ionosphere

5510 Auroral zone magnetic effects
MAGNETIC FIELD DISTURBANCES OVER AURORAL ARCS OBSERVED FROM SPITSBERGEN
B.S. Lanchester (Department of Physics, University of Southampton, Southampton, UK) D.U. Wallis
Coincident two station optical auroral data and magnetic field measurements from the polar-orbiting satellite HEOS2 have allowed the comparison of the positions of small-scale disturbances in the magnetic field with the positions of optical forms over Spitsbergen. For one discrete arc seen at 0715UT on January 15, 1969 we have found at the position of intersect between the satellite and arc, a narrow sheet of enhanced current density imbedded in a broader region of lower current density and which appears to mark the poleward boundary of the upward current region (region 2). Other simultaneous optical and magnetic field measurements made at 1500UT on January 19, 1986 indicate that multiple arcs were extended in the broad region of upflowing current, with a bright arc close to the boundary between the auroral oval and polar cap. (aurora, arc, Birkeland current)
J. Geophys. Res., A, Paper 4A0453

5540 Ion densities and temperatures
ELECTRON DENSITY AND WHISTLER MODE PROPAGATION CHARACTERISTICS AT 7000 KM ALTITUDE IN THE AURORAL ZONE AND POLAR CAP
M. Temerin (Space Sciences Laboratory, University of California, Berkeley, CA 94720)
An instrument of the electric field wave spectrum by the S3-3 satellite has shown the upper frequency cutoff of the whistler mode wave to be below 10 kHz. This measurement shows that the electron density in the polar cap can be as low as 1 cm^{-3} at 7000 km. However, since the measurement is unique in that it examined data set of the S3-3 satellite, such low densities must be rare both in the polar cap and in the auroral zone, except perhaps in regions of upgoing ion beams where whistler mode waves are usually not detected. This low density is confirmed by a measurement of the local lower hybrid frequency. The spin modulation of this wave amplitude as a function of frequency was used to determine that the wave was propagating down the magnetic field line. (Plasma density, wave propagation, whistler mode, plasma frequency)
J. Geophys. Res., A, Paper 4A0411

5545 Ionospheric disturbances
F-REGION 1-10 KM IRREGULARITY SPECTRA NEAR ARMA-MAL MULTIPLANATION AND SHEAR REGIONS
Santosh Kane (Hunnaut College, 400 The Fenway, Boston, MA 02115), Sunitha Basu, L. MacKenzie, N.B. Datow, W.B. Hanson, and C.S. Lin
Spectral characteristics of auroral F-region irregularities were studied by the use of high resolution (~35 m) density measurements made by the retarding potential analyzer (RPA) on board the Atmosphere Explorer-E (AE-E) satellite during two orbits when the satellite was traversing the high latitude ionosphere in the evening sector. Coordinated radar passes provided magnetic coverage of auroral activity. The auroral energy input was estimated by inspecting the low energy electron (LEF) data on AE-E. It was found that the rms-differential ion-flux spectral index (ρ1) of the irregularities at scalelengths <1 km showed consistent steepening in regions of large auroral acceleration events with ρ1 values >3. This is interpreted as resulting from the effects of E-region conductivity on F-region irregularity structure. The regions in between the precipitation structures, where presumably the E-region conductivity was small, were generally associated with large shears in the horizontal E×B drift and/or velocities as measured by the ion drift meter on board AE-D. The maximum drifts measured were ~2 km sec^{-1} corresponding to an electric field of 100 mV/m. The large velocity regions were also associated with substantial ion-heating and electron-density depletions. The largest shear magnitudes observed were ~40 msec^{-1} km^{-1} and the shear gradient scalelengths were ~10 km which was approximately the resolution of the ion-drift meter data set used. The spectral characteristics of irregularities in the large, variable flow regions were very different with ρ1 being ~1. Since these regions were also associated with the largest irregularity amplitudes, it seemed probable that either the velocity shears or, alternatively, the large velocities, provided a source of irregularities in the auroral F-region ionosphere. Current work on plasma instabilities related to velocity shears and two-dimensional fluid turbulence is briefly summarized and critically compared to the findings of the present study. (F-region irregularities, inverted-V precipitation, electric fields)
J. Geophys. Res., A, Paper 4A0455

Particles and Fields—Magnetosphere

5710 Short-period (< 1 day) variations of magnetic field
RELATIONS BETWEEN POLARIZATION AND THE STRUCTURE OF ULF WAVES IN THE MAGNETOSPHERE
D. J. Southwood (Inst. of Geophys. & Planetary Physics, Univ. of California, Los Angeles, and Dept. of Physics, Imperial College, London), and M. G. Kivelson (Inst. of Geophys. & Planetary Physics, and Dept. of Earth & Space Sciences, Univ. of California, Los Angeles)
Large-scale low-frequency ULF signals in the terrestrial magnetosphere are expected to have the structure of standing waves along the ambient magnetic field and to propagate across the field. By making simple assumptions regarding the wave form, we show that wave polarization in a plane perpendicular to the magnetic field, B_0, may be interpreted in terms of the signal structure across B_0. Two cases are distinguished, corresponding to a pure Alfvén mode (transverse) wave and a purely compressional wave. Examining published ULF data, we find that many compressional signals appear to have transverse polarization more appropriate to the Alfvén mode. We conclude that the compressional signals are commonly coupled to Alfvénic disturbances, but there is evidence of purely Alfvénic signals as close.
J. Geophys. Res., A, Paper 4A0418

5770 Short-period variations of magnetic field
HARMONIC STRUCTURE OF PC 3 – 5 MAGNETIC PULSATIONS OBSERVED AT THE SYOWA-MIZUHARA CONJUGATE PAIR
Y. Tonegawa (Department of Astronomics and Astronautics, Tokai University), 1117 Kitakaname, Hiratsuka 259-12) and R. Fukunishi
Strong evidence for the harmonic structure of Pc 3 – 5 magnetic pulsations observed on the ground has been provided by extracting coherent oscillations from magnetic pulsation data recorded at the Syowa-Mizuhara conjugate pair near $L = 6$ and then by calculating the difference of the H components between the two points as a function of local time. The calculation suggests that the Pc 4/5 band consists of the frequency range of ~3 – 10 mHz is fundamental mode of standing shear Alfvén wave near $L = 6$, while the 3 band with multiple harmonic structure observed in the frequency range of ~20 – 100 mHz is the higher harmonics (usually third to sixth harmonics). The second harmonic is not notable compared with other harmonics. It is found further that the fundamental mode and the higher harmonics are not always excited simultaneously. Therefore, it is likely that when the frequency of the external driving source is in the Pc 4/5 range, it excites higher harmonics of standing shear Alfvén waves near $L = 6$, while when the frequency of the external driving source is in the Pc 3 range, it excites a fundamental mode. (Magnetic pulsations, harmonic structure, conjugate pair)
J. Geophys. Res., A, Paper 4A0452

5770 Short-period variations of magnetic field
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Y. Tonegawa (Department of Astronomics and Astronautics, Tokai University), 1117 Kitakaname, Hiratsuka 259-12) and R. Fukunishi
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J. Geophys. Res., A, Paper 4A0452

Planetology

5705 General (Surface of Venus)
NEW DATA ON THE COMPOSITION, STRUCTURE AND PROPERTIES OF VENUS ROCKS, OBTAINED BY VENERA-13 AND VENERA-14
Yu. A. Surkov, (117975, Moscow, GSP-1, Kosygin St., Vernadsky Institute of Geochemistry and Analytical Chemistry USSR Academy of Sciences), V. L. Barsukov, L. P. Moskalyeva, V. P. Kharyukova and A. Ye. Kemurdzhian
The study of the composition, structure and properties of Venus rocks was carried out by Venera-13 and Venera-14. The main structural-morphological types of province of Venus surface were chosen for the study. The radial and mineralogical composition of the rock at the Venera-13 landing site show that it belong to the group of weakly differentiated melanocratic alkaline gabbroids; at the Venera-14 landing site Venus rock are similar to the Earth's oceanic tholeiite basalts. The interesting specification of the surface rock is the great number of the lamellar, visible on the panoramas of the landing sites. The measurement of physical and mechanical properties shows that the Venus rocks have friable, weakly consolidated porous structure. Analysis of the information from the γ-, β-, γ-10, -13, -14 led to conclusion that the most likely global process, which is responsible for the formation of present rocks is volcanic eruptions. Moreover, due to the low gas contents of basaltic melts eruptions of the type of an explosive character leading to the formation of sedimentary type rocks. (Planetology, solid surface, chemical composition, Venus rocks)
J. Geophys. Res., B, Paper 4B0403

Strong evidence for the harmonic structure of 3 – 5 magnetic pulsations observed on the ground has been provided by extracting coherent oscillations from magnetic pulsation data recorded at the Syowa-Mizuhara conjugate pair near $L = 6$ and then by calculating the difference of the H components between the two points as a function of local time. The calculation suggests that the Pc 4/5 band consists of the frequency range of ~3 – 10 mHz is fundamental mode of standing shear Alfvén waves near $L = 6$, while the 3 band with multiple harmonic structure observed in the frequency range of ~20 – 100 mHz is the higher harmonics (usually third to sixth harmonics). The second harmonic is not notable compared with other harmonics. It is found further that the fundamental mode and the higher harmonics are not always excited simultaneously. Therefore, it is likely that when the frequency of the external driving source is in the Pc 4/5 range, it excites a fundamental mode. (Magnetic pulsations, harmonic structure, conjugate pair)
J. Geophys. Res., A, Paper 4A0392

What Is the Lithosphere?

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What is the lithosphere? What things subduct, what things do not, and why? How is the lower continental crust formed? Where are the large-ion lithophile elements stored? Is the style of plate tectonics episodic? These and related questions were considered during a workshop held at the University of Texas at Austin in March 1982 under the sponsorship of the U.S. Geodynamics Committee (USGC). The objectives of the workshop were somewhat unusual in that participants were asked to identify assumptions underlying proposed models and hypotheses, with special emphasis on controversies inherent in the various models. No attempt was made to reach consensus. The flavor of the discussions is indicated by the questions above, devised by a steering committee, each serving as the point of departure for approximately one half day of the wide-ranging discussion.

The rationale for the workshop is summarized in the first paragraph of the report (*The Lithosphere, Report of a Workshop*, National Academy Press, Washington, D. C., 1983): "The plate tectonics model has been remarkably successful in rationalizing the kinematics of surficial materials of the earth's interior. A key element of the plate tectonics model is that the outer rigid shell of the earth is made up of discrete plates capable of independent motion with respect to each other. By convention, this assemblage of plates constitutes the earth's lithosphere. According to existing models, the lithospheric plates are formed at ocean ridges and descend into the earth's interior at subduction zones. Knowledge of the lithological and petrological characteristics of this lithosphere is thus a major element in understanding the dynamic processes of the outer layers of the earth."

At the workshop, Don Anderson noted the differing criteria that have been applied in identifying the lithosphere. Originally defined as the outer stony shell of the earth, it was later defined to include the following: elastic or flexural lithosphere, calculated from surface adjustments of loading and unloading, usually between 20 and 30 km thick; thermal lithosphere, the cool outer layer of the earth which supports a conductive thermal gradient and is computed to be about 100 km thick; and seismic lithosphere, overlying the widespread, though not necessarily world-wide, seismic low velocity zone (LVZ). The depth of this zone may be less than 45 km beneath young oceans and, if identifiable, is about 150 km beneath the continental shields; the LVZ is generally, but perhaps erroneously, equated to the asthenosphere. A chemical-mineralogical lithosphere may be postulated if the outer portion of the mantle is layered or grossly heterogeneous.

The assemblage of rigid independently translating plates constituting the plate tectonic model may not be identical with any of the above concepts of the lithosphere. In general, rigidity is the controlling factor. However, for continental plates it has been suggested, on the basis of seismic travel time in the upper mantle, that the lower boundary may lie beneath low density mantle material bonded to the crust and is hence much deeper than that of the thermal lithosphere.

An upper mechanically strong layer and an underlying weak zone are essential components of the plate tectonic model. There is, however, no general agreement on the physical nature of their mutual boundary or the parameters that must be measured to define it. The physical characteristics of the lower lithosphere also remain unclear. Observations of fundamental-mode surface waves and magnetotellurics do not allow the vertical resolution necessary to reveal detail in this dynamically important region. The most promising approach may be the study of full seismic wave forms using synthetic seismograms and array methods to map the three-dimensional variations of this boundary.

Crust and Upper Mantle

The two major seismic discontinuities that divide the earth into crust, mantle, and core have been known for many decades, but their precise character is still uncertain. The Moho beneath oceanic crust is commonly related to an ophiolite model, the velocity difference being due either to a cumulate ultramafic zone beneath gabbro or to a contrast between upper serpentinized and underlying less serpentinized ultramafic mantle rocks. The drilling of deep holes in oceanic crust is perhaps the only way to resolve this uncertainty. The nature of the Moho beneath continents is even more conjectural. Seismic refraction data usually reveal a distinct Moho. However, deep crustal reflection profiling seems to show a discontinuous, layered zone approximately at Moho depth. Proposed interpretations of this zone include layered metasediments, cumulate layering, tectonic banding, sill-like intrusions, and lenses of partial melt. The Gutenberg discontinuity between mantle and core is characterized by a zone of scatter in seismic velocities. If convection in the core is maintained by thermal energy, this zone may correspond to a thermal boundary layer, which in turn would imply deep mantle convection.

Seismic discontinuities have also been recognized at depths near 650, 400, and 220 km. The low velocity zone for shear waves lies above the 220 km discontinuity. The cause of the low velocity is much debated. Crystal orientation by mantle flowage, partial melting of mantle material, and chemical differences are suggested causes. The 400-km, and especially the 650-km, discontinuities are strongly reflective and apparently can be mapped over large areas. The discontinuity at 400 km is commonly regarded as a phase transition, either olivine to spinel structure or pyroxene + garnet to a garnet solid solution. It has recently been suggested that the 220 and 650 km discontinuities represent boundaries between chemically distinct regions in the mantle. The 650 km discontinuity is close to the maximum depth of observed earthquakes; a thermal boundary layer related to mantle convection has been postulated for this discontinuity, but not for those at 220 and 400 km.

Observed lateral variations with age of thermomechanical, seismic, and electrical properties of the oceanic lithosphere can be closely approximated by thermal models. However, lateral heterogeneities within the continental crust, beneath the continent-ocean boundaries, or deep within the mantle remain poorly understood. For the ocean-continent boundary, one school of thought suggests that significant deep thermal heterogeneity is prevented by the development of instability in a thermal boundary layer; another suggests that continents have deep roots, the expression of a chemical boundary layer. Consequences of these two models are quite different for plate tectonics and global geochemical balances. New long-period digital seismic networks, higher mode surface-wave regional studies, and perhaps electrical conductivity surveys are promising methods for mapping large-scale lithospheric structural and lithologic variations.

High electrical conductivity anomalies in the deep crust beneath the continents are evidence for lateral inhomogeneity of shield areas. Interpretation of the anomalies in terms of either partial melt or high water content is controversial. The high conductivity seems to suggest that the lower continental crust is in a dynamic state.

The most notable global event related to continents in the last 250 m.y. was the formation and subsequent breakup of the super continent Pangea. Was this an accident, or do major episodes of rifting always begin within very large continental masses? If the latter is the preferable hypothesis, does this mean that the present seafloor spreading in the Pacific had its origin in the breakup of an earlier giant continent? This may be a realistic scenario. Paleomagnetic measurements show that the earth had a magnetic field at least 3.4 b.y. ago and that apparent polar wander at rates comparable to those of the past 150 m.y. has occurred through geologic time.

There were intervals of the earth's history when the major continental masses remained fixed for long periods, and there were episodes when magnetic reversals were rare or absent. There were also periods when apparent or true polar wander was particularly rapid. The apparent correlations between the above observations lend some credence to the speculation of a cause-and-effect correlation between core processes and mantle convection. A possible explanation is that changes in the spin axis of the earth are not followed immediately by corresponding changes in the direction of the spin axis of the inner core. Such differences could result in a reversal in direction of the main magnetic field. Reversals, therefore, may arise as a result of changes in the direction of the earth's spin axis caused by movements of the plates at the surface, which also affect the convective and thermal regimes of the mantle.

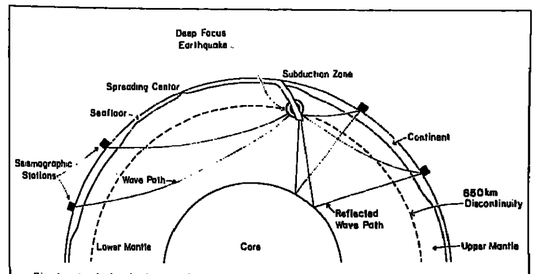


Fig. 1. Analysis of seismic velocities indicating possibility that a cold high-Q slab extends into the lower mantle. (Source: Redrawn from T. H. Jordan, *Mosaic, 12*, 1981. Reprinted with permission.)

Dynamics of Tectonic Plates, The Geoid, Hot Spots, and Convection

The general pattern of plate movement over the last 150 m.y. is reasonably well known, and there is wide agreement that the basic driving mechanism is some form of convection in which the lithosphere itself may be an active component. However, important questions remain: How are rifting and spreading initiated? What determines the pattern of seafloor spreading? Are the processes leading to rifting and basin formation the same? Is convection in the mantle layered or whole mantle? Are phase changes and partial melting more important than thermal expansion? What are the roles of continental insulation and subductive cooling?

Suggested events leading to initiation of rifting include thermal pulses, plate collisions, sedimentary loading, crustal stretching, phase changes, and effects of continental insulation and membrane stresses induced by true polar wander. Questions abound: Is continental rifting driven by thermal processes from below, perhaps dominated by hot-spot activity? Why do oceanic ridges commonly assume a configuration of perpendicularly spreading ridge segments and a transform fault system that approximates the irregular shape of an initial break? Why do some rifts continue to develop into ocean basins while others fail to do so? Does rifting follow periods of rapid true polar wander?

The process by which subduction is initiated is also poorly understood. A large amplitude disturbance is needed because both continental and oceanic lithosphere are stabilized against small amplitude vertical deflections. Flexural strength permits damping of perturbations and isostasy prevents buckling. No generally accepted models exist for the initiation of subduction. The rate and mechanisms of assimilation of subducted lithosphere are also unknown. In the plate tectonics model, the downgoing slab is a driver of plate motions, a probe to mantle rheology, a carrier of chemical contaminants, and a cooling agent for the hot mantle. Conductive thermal models for the heating of subducted slabs indicate that the approximately 80 million-year residence time between the surface and 670 km is inadequate to allow thermal re-equilibration of the slab. At this depth, therefore, the slab should still have a density in excess of that of the surrounding mantle. Travel time residuals have, in fact, been interpreted as indicating presence of slabs to depths of 1000 km, well into the lower mantle (Figure 1), though the evidence has been questioned.

One of the most exciting opportunities for decades to come is that of directly mapping patterns of flow within the upper mantle by measuring seismic anisotropy. The theoretical framework necessary for describing propagation of seismic waves in a spherical anisotropic earth has been developed recently. Such measurements could, for example, supply independent evidence of the validity of the important concept that hot-spot traces provide a reference frame for motions of the lithosphere plates relative to underlying mantle.

Hot spots are the surface manifestation of a widespread planetary process that we do not yet understand. Are they related to cracks in the plates, or do they represent a fundamental component of mantle convection? Hot spots apparently persist for tens of millions of years and move only very slowly with respect to each other. They thus provide a useful frame of reference. Motions with respect to the hot spots are the chief observations constraining models of plate-driving mechanisms, as discussed below.

Hot-spot magmas and contained xenoliths provide much of what we know about the mantle's petrology and geochemistry, but questions still abound. For example, do the different geochemical signatures seen among active hot-spot volcanoes persist through time, or do individual hot spots have as much variation over their lifetime as that observed among currently active hot spots? Do ancient hot-spot intrusions have the same geochemical characteristics as modern ones? Could these similarities or differences be used to discriminate among models of mantle evolution? To what depths do the roots of hot spots extend (Figure 2)? What causes hot spots? Are they related to a mantle convection system? Does the starting up or fading out of hot spots trigger episodes of true polar wandering?

Recent studies of the geoid demonstrate a strong correlation between hot spots and long wave length geoid highs, although the hot spots themselves cannot be the sole source of excess mass to produce these highs. Both tend to lie near the equator. The geoid highs also correlate with regions of extensive continental Cretaceous volcanism. Gondwana may have lain approximately over the Atlantic-African geoid high during the Permian; this possibility has led to the suggestion that continental insulation is a prime factor in the location and generation of hot spots (Figure 3).

While the geoid highs are centered over the equator, the Atlantic-African region and the central Pacific, geoid lows are concentrated in a polar band, which at present also contains much of the continents and ancient shields. Continents may have migrated to these lows (presumably related to colder mantle) and away from hotter mantle, perhaps a product of continental insulation and the absence of subduction-related cooling processes in a previous cycle. Africa is situated on a geoid high but is fragmenting. If the geoid highs form under continents in polar regions, they will rotate the continents to the equator,

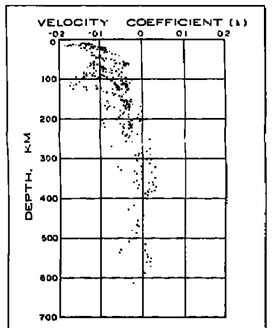


Fig. 2. Velocity structure under the Yellowstone caldera. The normal velocity multiplied by the velocity coefficient (*h*) shown along the abcissa gives the velocity anomaly. Each point in the scatter diagram is based on one residual value. Note that no seismic "root" is evident below 300 km. Does the Yellowstone hot spot have its origin near this depth? (Source: Reprinted from H. M. Iyer et al., *Geol. Soc. Am. Bull., 92*, 792–798, 1981. Reprinted with permission.)

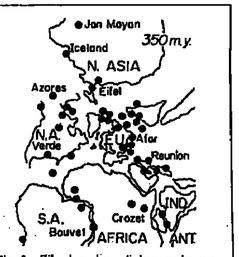
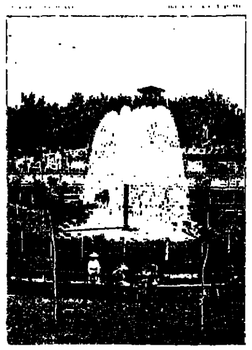


Fig. 3. The location of the continents about 350 m.y. ago. Also shown are hot spots, most of which are currently in the Atlantic and Indian oceans and under the continent of Africa. The continents moved slowly north during the next 150 m.y. and then broke up and dispersed to their present locations. The majority of present-day hot spots were beneath Gondwanaland for a long period of time prior to 200 m.y. ago and may have formed as a result of continental insulation. (Source: Reprinted from D. L. Anderson, *Episodes, 3*, 307, 1980. Reprinted with permission.)

Article (cont. on p. 324)

WaterWatch



WaterWatch
News of the hydrology scene

Editor: Mary P. Anderson, Department of Geology and Geophysics, University of Wisconsin-Madison, Madison, WI 53706 (608-262-2389)

News & Announcements

Coaxing Clouds Over Jerusalem

It is raining 15% more in certain parts of Israel these winter days, and the man responsible for it is Avraham Gagin of the Meteorological Department of Jerusalem's Hebrew University.

Gagin heads the research that has made Israel the world leader in artificially induced precipitation, where the population currently consumes more than 95% of the available water supply.

Using the conventional methods of cloud seeding, the injection of a fine powder of silver iodide into a cloud, Gagin modestly says, the "powers" of his staff lie in knowing which clouds to seed. "We don't make rain," he says, "we simply encourage the rain-producing cloud to let down more precipitation than it ordinarily would have." Israelis batter the clouds with silver iodide from above and below. Crop dusting planes are used, spraying the chemical into the clouds from generators under the wings. From the ground, silver iodide is sent up through vast batteries of generators located throughout the country.

Although in 1982-1983 Israel experienced one of the wettest winters in recorded history of this area, Israel's water reserves are not only low, but have reached what some experts call a "crisis level." Israel's two main water sources are the Sea of Galilee in the north, fed by the Jordan River, and natural underground reservoirs from which water is pumped to the surface through artesian wells. In spite of the heavy rainfall, the Sea of Galilee is still at its lowest level in 20 years and aquifers are in danger of drying out, consequently suffering damages that can interfere with a smooth water flow. Some critics object to the rainmaking project saying it tampers with nature. Gagin, who sees their point of view, says that "to get back to natural rainfall, we would have to go back thousands of years," before such phenomena as defoliation from overgrazing and the felling of trees influenced the annual rainfall.

The induced rainfall seems to be reversing the depressing situation of water supplies in Israel and, for that matter, in countries that border Israel. When rain-making activities were started, the attempts were a well-kept secret, for no one knew how the cloud seeding would affect the weather of the neighboring Arab states. But when the University of Chicago published data from studies in Arab countries next to Israel, a 20% increase in rainfall was showing up in Jordan, Lebanon, and Syria. Authorities here assume that the Arabs were "not displeased." Israel's rain-making techniques are benefiting countries outside of the Middle East. Recently, a delegation of leading meteorologists and water conservationists from South Africa came to Jerusalem to learn from the experts here. In addition, Israeli meteorologists have been dispatched to Peru where an Israeli company, Agridev, has been employed to develop a vast arid area of that Latin American country.

This item was submitted by Ellen Davidson, *Office of the Consulate General of Israel, New York.*

On The Waterfront

The following members of the Hydrology Section have been selected to receive Presidential Young Investigator Awards (*Eos*, March 13, 1984, p. 97).

Roman Krzystofowicz, Univ. of Virginia; ***Daniel R. Lynch***, Dartmouth College; and ***Jery R. Stedinger***, Cornell Univ.

Orie L. Loucks has been appointed the new director of the Holcomb Research Institute, Indianapolis. He has established three areas of research for the Institute: water sciences, biotic resource analysis, and environmental economics and policy analysis. The water sciences program initially is being developed around the existing Ground Water Modeling Center currently based at the Holcomb Research Institute.

Opinion

Mesoscale Meteorology/ Hydrology Experiment?

Scientific progress in the field of surface water hydrology appears currently to be constrained by a lack of comprehensive field data involving the coordinated simultaneous observation of many meteorological and hydrologic variables at mesoscale. Mesoscale meteorological experiments are under active discussion by (1) a U.S. interagency team and (2) the World Climate Research Program. The hydrologic research community should ensure that its interests are represented in the planning for these unique experiments.

Historically, the field of surface water hydrology has grown out of an engineering need to provide adequate water supplies over the long-term and to provide flood protection in the short term. Early work involved the collection and analysis of station records of precipitation and streamflow, and their use in developing lumped (i.e., one-dimensional) models of the precipitation-runoff behavior of watersheds.

As the field has matured, and as the observational and analytical tools have developed, we wish and need to ask more sophisticated questions:

1. Our growing interest in the behavior of larger physical systems and in climatic regimes having predominately convective storms demands that we deal explicitly with the spatially distributed character of both the atmospheric forcing and the land surface.
2. Our concern with the large-scale environmental impacts of proposed tropical macro-engineering projects such as deforestation in the Amazon Basin and drainage of the White Nile swamps requires that we consider the interactive behavior of the land surface/atmosphere system.
3. Improvement in short-term hydrologic forecasting, be it for flood warning or for other operational purposes, such as the control of irrigation releases, must involve inclusion of some of the physical/dynamical aspects of precipitation formation.

Advance in these areas requires both clever modeling and comprehensive data sets, and the latter do not exist. It is the opinion of many hydrologists that our science is currently constrained by the absence of such data.

Our Precipitation Committee has undertaken a multi-disciplinary effort to define and stimulate the analytical and experimental precipitation research needed by hydrologists. This Committee is chaired by Vijay K. Gupta of the University of Mississippi, and its membership contains physicists, atmospheric scientists, mathematicians, and statisticians in addition to hydrologists. They have organized a session at the Spring 1984 AGU meeting on Investigations on Mesoscale Precipitation Fields, which is jointly sponsored by the Hydrology and Atmospheric Sciences Sections, and have prepared an article on precipitation research which should appear shortly in *Eos*.

We hope that this statement of our interests and needs will help bring about a similar interdisciplinary effort on the experimental side.

Peter S. Eagleson
President
AGU Hydrology Section

Hydrologist Certification: Two Views

I recently received a letter regarding the registration of hydrologists but paid little attention. Now with Peter S. Eagleson's, president of the Hydrology Section, comments in *Eos* (Jan. 10, 1984, pp. 9–10) I realize there must be quite a controversy. I would like to comment, particularly with regard to the argument that registration will protect the public.

I am a registered professional forester in California. Therefore I am qualified to practice there. Correct? Legally, yes. Professionally, in most regards, no. I have never done the type of forestry work for which the registration law was primarily designed. My experience has been primarily with brushfields and rangelands or with tree species of the subtropics.

With 25 years in forest hydrology research and water resource planning, I could almost surely qualify for registration as a professional hydrologist. My studies include undergraduate and graduate courses in hydrology at the University of California, Berkeley, and Colorado State University. I consider myself a forest hydrologist, but to modify that to professional hydrologist would be to claim a general level of competence I likely do not have.

Finally, initials are no real protection to the public. I have just finished reading a report by a consulting engineering firm. The report is authored by five PE's and two CPAg's. The report is mostly about trees. It is also mostly incorrect. It is error ridden and full of unsupported, inconsistent, and unknowledgeable statements. The authors were unprofessional in this case since they did not make sure that someone among them understood how trees grow. As a result the buyer of that report was ill served in spite of all the initials behind the authors' names. I am afraid that unprofessional "professionals" will always be with us in spite of everything.

Hydrology is interdisciplinary by definition. I cannot imagine a hydrologist worthy of the name who does not have a core profession such as meteorology, engineering, agriculture, or even forestry. Requiring a named profession as a prefix, as in forest hydrologist, would be far more meaningful to the public than the term "professionals."

Let's leave it at that rather than trying to decide who is, and who is not "professional."

Robert A. Merrium
Kailua, Hawaii

I applaud the decision of the Hydrology Section Executive Committee in remaining neutral in the debate concerning government certification of hydrology professionals. The two reasons cited in Water Watch in *Eos* (January 10, 1984, pp. 9–10) are indeed the ones usually put forth by those in favor of state certification. There is, however, a third reason that is seldom stated but nevertheless very much a factor in the minds of many of those behind the certification movement: the regulation of competition, particularly the entrance of new practitioners into the marketplace. By controlling the numbers of practitioners through licensing requirements, state accredited professionals—particularly those who are "grandfathered" in when the law is passed—can limit competition and command a larger share of the available market for professional services.

We are now seeing a trend toward reduced government regulation of many industries. It will be unfortunate if hydrologists overlook the reasons for and benefits of this trend and instead pursue greater regulation of their own profession. Certification of professional excellence can be readily accomplished within the framework of professional societies such as the American Society of Civil Engineers without resorting to legal mechanisms to control who can and cannot practice.

Gary R. Holzhausen
President
Applied Geomechanics, Inc.

Meetings

Hydrology Days

The AGU Front Branch is sponsoring three Hydrology Days to be held April 24–26, in the Student Center at Colorado State University in Fort Collins, Colo. Student papers will be presented on the first day, and professional papers will be presented on the second and third days. John Bredehoeft, U.S. Geological Survey, will be the featured speaker at a luncheon on the first day of the program. The title of his talk will be "Water Management: Who are the Managers?" For more information contact H. J. Morel-Seytoux, Colorado State University, Civil Engineering Department, Fort Collins, CO 80523 (telephone: 303-491-8549).

Penrose Conference

A Geological Society of America Penrose Conference on Transport Processes in Fractured Rock, will be held from September 24 to 28, 1984, in Park City, Utah. The objective of the conference is to bring together recent advances in our understanding of the physics of mass and heat transfer in fractured porous media, in simulation methodologies for mass and heat transfer, and in the experimental determination of system parameters. The conference leaders are Leslie Smith and Frank Schwartz. Participation is restricted to about 80 people. For more information contact Leslie Smith, Department of Geological Sciences, University of British Columbia, 6339 Stores Road, Vancouver, BC, Canada V6T 2B4.

Gordon Research Conference

A Gordon Research Conference on Modeling of Flow in Permeable Media will be held in Andover, N.H., July 30 to August 3, 1984. The purpose of the meeting is to discuss current issues in the modeling of fluid flow phenomena in permeable media. Invited speakers include J. Bear, J. R. Philip, P. A. Witherspoon, R. W. Gillham, H. C. Helgeson, F. A. Hewett, H. C. Hardee, K. O'Neill, F. M. Richter, J. Noorishad, J. Wheeler, T. Pomerantz, I. Dull, R. Ewing, P. Sammon, J. Bell, J. Wallis, A. Weiser, L. W. Gelhar, W. A. Jury, and S. P. Neuman. The chairman of the meeting is T. N. Narasimhha, Earth Sciences Division, Lawrence Berkeley Laboratory, Berkeley, Calif. Participation is limited to about 100 participants. Applications may be obtained from A. Cauickshank, Gordon Research Conferences, Pastore Chemical Laboratory, University of Rhode Island, Kingston, RI 02881.

Sink Hole Conference

The first multidisciplinary conference on sink holes will be held October 15–17, 1984, in Orlando, Fla. Geologists, engineers, geographers, and others from related disciplines are invited to attend and present papers. The conference is being sponsored by the Florida Sinkhole Research Institute, University of Central Florida, College of Extended Studies, Orlando, FL 32816–0177.

Irrigation and Drainage Congress

The 12th International Congress on Irrigation and Drainage will be held in Fort Collins, Colo., from May 28 through June 1984. The American Water Resources Association (AWRA) is one of more than 20 cooperating organizations sponsoring the conference. There will be a special session on the impact of the energy crisis on irrigation and drainage and a symposium on new developments in the protection of irrigation, drainage, and flood control structures on rivers. For more information contact Larry Stephens, Executive Secretary, U.S. Committee on Irrigation, Drainage and Flood Control, P.O. Box 15326, Denver, CO 80215 (telephone: 303-234-3006).

National Water Well Conference

The National Water Well Association (NWWA) is sponsoring a conference on the Practical Applications of Ground Water Models to be held in Columbus, Ohio, on August 15–17, 1984. The NWWA is also sponsoring the 7th National Ground Water Quality Symposium, September 26–28, 1984, in Las Vegas, Nev. The theme of the conference is "Developing and Implementing Innovative Means of Dealing with Potential Sources of Ground Water Contamination." Abstracts are due May 25, 1984.

For more information on both conferences contact David M. Nielsen, NWWA, 500 West Wilson Bridge Road, Worthington, OH 43085 (telephone: 614-846-9355).

ACS Groundwater Sessions

The American Chemical Society (ACS) will hold a series of 6 sessions on groundwater in a 3-day period during a national meeting of the ACS to be held April 28 to May 3, 1985, in Miami, Fla. All papers will be invited. For more information contact Willa Garner, U.S. Environmental Protection Agency, Washington, D.C. (telephone: 703-557-0320).

AGU Fall Meeting: Statistical and Hydrological Criteria in the Safety of Dams

The AGU Surface Runoff Committee is organizing a special session on dam safety at the Fall 1984 meeting in San Francisco.

During the last few years, research has been directed toward the analysis of risks and uncertainties, risk-based design and analysis of statistical, geotechnical, and hydrologic issues in the safety of dams. This session shall focus primarily on risk and hydrological factors associated with the design and safety of dams. Papers are solicited dealing with risk-based design, quantification of risks, uncertainties and probabilities of failure, stochastic aspects of reservoir operation related to flood control and dam safety, dam break problems, and hazard identification. General papers dealing with the mechanics of flow in dam-break situations may be accepted for presentation. The focus of the session will, however, be on risk and reliability aspects of dam safety. Invited papers deal with the use of random field models, probabilistic risk analysis, determination of the composite risk of failure, risk-based design, reservoir operation and dam safety, and relationships of failure probabilities to earthquakes and flood insurance.

Please mail three copies of your abstract to AGU and one to U. Lall, Department of Civil Engineering, 3012 MEB, University of Utah, Salt Lake City, UT 84112 (801-581-6701), the session organizer.

Deadline for special session: August 15, 1984.

Remote Sensing and Remote Data

The American Society for Testing and Materials (ASTM) is sponsoring a Symposium on Geotechnical Applications of Remote Sensing and Remote Data Transmission in mid January 1986 at New Orleans, Organized by ASTM Committee D18 on Soil and Rock, the 1-day symposium will be one part of the 4-day spring meeting of that committee.

The purpose of the symposium will be to develop information that can be used to prepare guidelines for the use of new remote sensing techniques for a variety of projects involving geotechnical engineering and to the use of satellite transmission for on-site instrumentation data. The program will be designed to show advantages and disadvantages of various remote sensing and remote transmission techniques, equipment, and programs related to soil mechanics, rock mechanics, geologic engineering, groundwater hydrology, and other scientific input to geotechnical engineering studies.

Offered and invited papers will be scheduled for oral or poster presentation. All papers will be reviewed and considered for publication in an ASTM Special Technical Publication. Presentations will be selected by a Program Committee on the basis of submitted abstracts. Prospective authors are invited to submit a title and a 300–500 word abstract to symposium chairman A. Ivan Johnson, Consultant, Woodward-Clyde Consultants, Harlequin Plaza-North, 7600 East Orchard Road, Englewood, CO, 80111 (telephone: 303-425-5610 or 303-694-2770).

To receive information on the symposium or for detailed instructions for submittal of abstracts, contact symposium chairman A. Ivan Johnson or Kathy Greene, ASTM Publications Division, 1916 Race Street, Philadelphia, PA 19103 (telephone: 215-299-5414).

Hydrology at Spring Meeting

The Hydrology Section will sponsor the following special sessions at the 1984 annual spring meeting in Cincinnati, (May 14–17):

Groundwater Transport: Field Methods, Mon. PM; Transport Processes I and II, Tues. AM and PM; Mesoscale Precipitation I and II, Tues. AM and PM; Catchment Geochemistry, Wed. AM; Hillslope Hydrology, Thurs. AM; Sediment Storage, Thurs. PM.

The general session on groundwater will be held Monday and Wednesday mornings. The general hydrology session will be held Wednesday afternoon.

Workshop on Hydrologic Applications of Space Technology

The International Association of Hydrological Sciences (IAHS) and the World Meteorological Organization (WMO) are planning for an International Workshop on Hydrologic Applications of Space Technology: Input to Hydrologic Models and Geographic Information Systems, to be held in Florida in mid to late 1985. The city and exact date will be announced later.

The workshop program will emphasize offered and invited oral or poster papers related to the input of remote sensing and remote data transmission to hydrologic models and geographic information systems. Field trips to NASA's John F. Kennedy Space Center and other points of scientific interest will be part of the program. An exhibit and demonstration of pertinent equipment, systems, and programs will be available, as will a display of related books and periodicals.

Organizations interested in exhibiting equipment, systems, or publications or in demonstrating equipment or software programs should contact A. Ivan Johnson, President, IAHS International Committee on Remote Sensing and Data Transmission, 7474 Upham Court, Arvada, CO 80003. Persons wishing to offer an oral or poster paper for consideration by the program committee should submit a typed single spaced original and one copy of a 400–600 word abstract, in English, to Mr. Johnson at the above address or to J. Nemec, Director, Hydrology and Water Resources Department, World Meteorological Organization, Case Postale No. 5, CH-1211 Geneva 20, Switzerland.

Meeting Reports

AGU Hydrology Section

The Executive Committee of the AGU Hydrology Section met in regular session at 4:00 P.M. on Thursday, December 8, 1983, in Room 378 of the Cathedral Hill Hotel, San Francisco, Calif. Seven board members were present with section president, Peter Eagleson, presiding.

Report of Meeting Chairmen

A total of 18 sessions were presented in San Francisco, and all were well attended, as was reported by program chairman Dennis Lettenmaier. Added to the regular sessions of General Hydrology, General Ground-water Hydrology, and Sediment Transport were the following special sessions: Glacier Ocean Interaction, presider Edward Josberger; Orinoco and the Amazon, presider Edward Andrews; Transport and Geochemical Interactions in Stream Water, presider F. E. Bencola; Instream Flow Requirements for Fish, presider Brian W. Mar; Multivariate Modeling of Hydrologic and Other Geophysical Time Series, presiders Jose D. Salas and David R. Dawdy; Optimization Techniques for Managing Ground Water and Stream Aquifer Systems, presider Steve Gorelick; Treatment of Evapotranspiration Soil Moisture Evolution and Aquifer Recharge in Watershed Models, presiders Arlen D. Feldman and Hubert J. Morel-Seytoux; Statistical Procedures for Estimating of Flood Risk at Gauged Sites, presider J. R. Stedinger; and Searching for More Physically Based Extreme Value Distributions in Hydrology, presider Juan B. Valdes. The session on Glacier Ocean Interaction received the most publicity, with numerous accounts of some of the presentations appearing in the newspaper. One of the pleasant surprises of the meetings was the high attendance at the special sessions on Optimization Techniques for Managing Ground Water and Stream Aquifer Systems and Multivariate Modeling of Hydrologic and Other Geophysical Time Series. Both sessions were highly interdisciplinary, attracting numerous scientists from other sections of AGU.

In his absence, a memorandum from John R. Ritter, the program chairman for the AGU Spring Meeting in Cincinnati, was given. Seven symposia or special sessions are planned for the Spring Meeting. Two sessions in Water Quality; one session in Stochastic Elements of Nonpoint Source Pollution Models and Water Quality and Geochemistry of Small Catchments; one session in Erosion and Sedimentation on Sedimentation Storage in Rivers and Estuaries; one session in Surface Runoff on Hillslope Hydrology; two sessions in Groundwater, Miscible and Immiscible Transport in Groundwater and Field Methods for Supporting Groundwater Chemical Transport Models; and one session in Precipitation on New Research Directions in Modeling of Precipitation in Space and Time. It looks like a full schedule of topics which should attract excellent speakers and audiences.

Reports of the Editors of Water Resources Research

Steve Burges reported that a mild editorial board meeting was held this year. With the dust of the page charge issue having settled, no major or resounding controversy was raised. Steve Burges introduced Ronald G. Cummings, the new editor of the social science side of *Water Resources Research*. Cummings stated that his goals were to continue the promotion of *Water Resources Research* as the journal for publishing high quality, policy sciences papers dealing with water-related topics, and to increase the level of participation and involvement with the journal by scholars in sciences concerned with systems analysis and operations research as well as the social sciences: economics, political science, law, history, and geography. Cummings has sent 1,500 letters to individuals in water research, department chairpersons, and directors of state water resource research institutes calling for quality, water-related papers dealing with policy issues. Cummings has added five new associate editors to his staff and has contacted previous and existing associate editors for continuity and assistance in the expansion of *Water Resources Research*.

In a memorandum to Peter Eagleson, Mary Anderson, the editor of Water Watch, a new hydrology news column appearing in *Eos*, reports that the first edition has appeared in early January. She also requested that anyone with ideas for a logo for the column should send them to her: Mary Anderson, Department of Geology and Geophysics, 1215 W. Dayton Road, University of Wisconsin, Madison, WI 53706. Contributions to future editions of the quarterly column are welcome.

Report of the Technical Committees

Eight of 10 technical committees submitted reports on their activities to present and their plans for the future. These reports will be sent to Mary Anderson to be abstracted and the abridged versions to be published in Water Watch. Those committees submitting the written reports were Erosion and Sedimentation, Water Quality, Precipitation, Surface Runoff, Policy Sciences, Soil Water, Snow and Ice, and History and Heritage.

Status of Soviet Hydrology

A written report was submitted by Nathan Buras to the Executive Committee on the status of the publication, *Soviet Hydrology*. Buras reports that, although *Soviet Hydrology* publishes translated papers from a broad range of sources, these papers seem to be specific technical applications of well-established principles. He points out that this does not diminish the value of these papers to professionals, but it is questionable whether or not they are of much use to researchers.

To be sure, high-quality papers are published in the Soviet scientific literature in the area of hydrology and water resources, but they are scattered in several periodicals. The important Russian publication is *Water Resources* which, it appears, is currently translated in toto into English. Another important source of original papers is the Doklady of the various sections of the Soviet Academy of Sciences. For example, important papers regarding the design and operation of surface reservoirs may be found in the section on cybernetics. Buras suggests that a screening board be established within the Soviet Union to help in the process of choice. Such a screening board was discussed with our Soviet colleagues in Hamburg, and its implementation is now being considered.

AIH

Peter Eagleson, section president, reiterated the Executive Committee's position in regard to the American Institute of Hydrology. AGU is a research body and, as such, should not be actively involved in the process of certifying hydrologists. He referred to a letter by Jay Lehr of the National Water Well Associa-

(cont. on p. 324)

EOS

Transactions, American Geophysical Union

The Weekly Newspaper of Geophysics

For speediest treatment of contributions send three copies of the double-spaced manuscript to one of the editors named below and one copy to AGU.

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Cover. This is a digitally analyzed X band synthetic aperture radar (SAR) image of waves in the coastal zone at the northern tip of the Goto Islands, Japan. The Goto Islands lie south of the island of Taushima and west of the Japanese island of Kyushu. The raw SAR image data were collected by the Japan Self Defense Air Force by using a Goodyear AN/UPD-4 system on an F-4 Phantom Jet. This scene was collected on November 29, 1981, at a speed of 270 m/s from an altitude of 3847 m. The radar depression angle was about 45°. The raw phase history was optically correlated on the precision optical correlator at the Goodyear Aerospace Arizona Division to create strip imagery on 70 mm film. Selected scenes on the film were scanned by a vidicon camera and were digitized and processed in the Remote Sensing and Image Processing Laboratory at Louisiana State University, Baton Rouge, LA. The digitized image resolution is approximately 10 m/pixel in this 512 x 512 pixel scene. Digital exploitation included geometric correction to the ground plane, local spectra creation, and detailed environmental analysis. Diagonal lineations superimposed upon the wave trains are aligned parallel to the surface wind of 9.8 m/s. Their periodic nature allow the surface wind direction to be accurately extracted from local spectra. These wind rows have been interpreted as resulting from convective roll vortices. Existing empirical relations and auxiliary weather data, in conjuction with wind direction and wave period extracted from the local SAR spectra, were used to estimate significant wave height and aerodynamic roughness parameters at the sea surface. Some of these estimated and extracted parameters are incorporated in this sea-state image, which combines original imagery, regionally processed spectra, and text symbols. This image was analyzed by Gary A. Mastin, Oscar K. Huh, and S. A. Hsu of the Coastal Studies Institute, Baton Rouge, as a part of research sponsored by the Coastal Sciences Program, Office of Naval Research, Arlington, Va. Special thanks are given to Kenji Wakui of the Japan Self Defense Air Force for supplying the raw data. (Figure courtesy of Gary Mastin, Sandia National Laboratories, Albuquerque, N.M.)

(cont. from p. 323)

tion where state certification activities are being promoted as opposed to national certification. It was a consensus of the Section Executive Committee that all further action or discussion about AIH come to an end.

Business Meeting

The business meeting of the AGU Hydrology Section met in a luncheon session at 12:00 noon on Wednesday, December 7, 1983, at the Holiday Inn Golden Gateway. The meeting was presided over by Section President Peter Eagleson.

Death of James Amorocho

It was with great sadness that Peter Eagleson announced the untimely death of James Amorocho of complications due to previous open heart surgery. Amorocho, a long-time member of AGU and past recipient of the Horton Award, had been active in the field of hydrology until the time of his death. He served on numerous section committees as an associate editor of *Water Resources Research* (WRR) and, at the time of his death, was chairman of the Horton Scholarship Committee. He will be missed by all.

New Editor of the Social Science Side of WRR

Ronald G. Cummings, professor of economics at the University of New Mexico, was introduced as the new editor of the social science side of WRR. Cummings promises to be an extremely active editor, continuing and expanding the past work of Jared Cohon, former editor.

Physical Science Editor of WRR

Steve Burges' term as editor of the Physical Science side of WRR expires in July 1984. Rafael L. Bras has been named chairman of the nomination committee to fill the vacancy. Suggestions for nominations should be sent to Rafael L. Bras, Ralph M. Parsons Laboratory, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139.

New Journal on Applied Hydrology

Some interest has been voiced among Hydrology Section members for the formation of a new journal on applied hydrology. An informal polling of the membership has been suggested. An opinion, for or against, should be sent by letter to Peter Eagleson, Room 48–335, Massachusetts Institute of Technology, Cambridge, MA 02139.

Policy Sciences Committee

The old Water Resource Systems committee has been reorganized and renamed. It is now known as the Policy Sciences Committee. The new committee chairperson is Helen Ingram, Department of Political Science, University of Arizona. Helen is a renowned scientist in the field of water policy and institutions.

Committee on History and Heritage

William Back has been named chairman of the History and Heritage Committee. This new committee will promote items, articles, and reports on the history of the hydrologic sciences. There are funds available for historical activities through the AGU Council.

Correspondence regarding the committee should be addressed to William Back, U.S. Geological Survey, National Center, MS 431, 12201 Sunrise Valley Drive, Reston, VA 22092.

Program Chairman

Peter Eagleson gave high praise to Dennis Lettenmaier for his excellent organization of this year's fall meeting. Dennis will continue on as Program Chairman for the Fall 1984 Meeting. All should be reminded that the Spring 1984 Meeting is to be in Cincinnati, Ohio, May 14–17.

Chapman Student Travel Fund

A general AGU fund, the Sidney Chapman Memorial Lecture Fund, is available for support for travel for a limited number of students to Chapman Conferences where no other travel funds are available. One student will be supported for a meeting of 60–90 attendees, two students may be funded for a meeting with over 100 attendees. The grants will cover economy airfare only.

Reserve Fund

The AGU Council has decided to maintain a liquid assets fund of 50% of annual expenses to allow AGU to weather a severe economic storm or to take advantage of unforeseen new opportunities. To reach this 50% goal, about 5% of expenses will be budgeted from surplus each year. This amounts to approximately $300,000 a year. The 50% goal translates into a reserve fund of $1,360,000.

Horton Award

This year's recipient of the Horton Award was David A. Woolhiser. Woolhiser is a research scientist for the Agricultural Research Station, Tucson, Arizona, and an adjunct professor of hydrology and water resources, University of Arizona, Tucson, Arizona. He received the award for his longstanding work in watershed systems.

Flood Estimation

The three sessions on flood estimation at the Fall AGU meeting were well attended and quite successful. A brief synopsis is provided here. On Wednesday, S. Yakowitz and K. Adamowski both illustrated how nonparametric procedures could be employed to estimate probability density functions. Such procedures do not require that one assumes that flood flows come from a pre-specified parametric family. Other papers addressed how information other than just the at-site gauged record could be employed to estimate flood risk. J. Salas discussed the use of record augmentation procedures based on bivariate Gumbel distributions. T. Cohn showed how "historical" records documenting the absence or occurrence of large floods could dramatically improve design flood estimates at gaged sites. Finally, G. Tasker proposed the use of generalized least squares (GLS) procedures for deriving estimators of flood quantiles as a function of basin characteristics; the GLS technique accounts for the sampling error and cross correlation of the flow quantile estimators. The procedure provided more accurate parameter estimates, much better estimates of the accuracy of the model's parameters, and an almost unbiased estimate of the prediction error.

During the formal morning session on Friday, several authors again considered the use of regional information in flood risk estimation. D. Wall discussed a study examining use of both historical flood records and of regional regression equations which also demonstrated the value of historical flood information. J. Herrin presented an evaluation of the Water Resource Council's pilot test of a wide range of procedures for estimating design floods for ungaged catchments. The "index flood" method and the U.S. Geological Survey's regression estimators were the most precise as well as being easy to apply. W. Thomas reported on the Water Resource Council's development of Bulletins 15, 17, 17a, and 17b; the uniform approach currently recommended is based on an evaluation of operational procedures available in 1974.

The use of regional information to improve flood estimates at gauged sites was addressed. C. Marin discussed an empirical Bayesian methodology and Monte Carlo results documenting its potential advantages. D. Lettenmaier presented another study; while certain empirical Bayesian procedures sometimes did well, others often did poorly in some respects.

The afternoon session addressed the use of "physically" based procedures for estimating flood flow distributions. Many questioned what that term means; V. Klemes indicated that such procedures employed models based on some reasonable theory relevant to the phenomena in question. R. Bras noted that when a theory is inadequate to predict the phenomena's behavior, one must fall back on calibration and parameter estimation procedures. In such cases, the supposedly physically based models primarily serve to define a parametric probability distribution whose parameters must be estimated from available flood data just as the parameters of normal, lognormal, and Pearson distributions are often estimated.

P. Todorovic advocated the use of partial duration series procedures. By using more information than just the largest peak observed each year, they could provide more accurate design flood estimates than annual flood series procedures. V. Gupta considered the characteristics of the arrival process of significant rainfall and flood events. Finally, R. Bras discussed his work with J. Valdes, M. Diaz, I. Rodriquez-Iturbe, and M. Gonzalez on instantaneous unit hydrograph procedures which provide an estimate of the distribution of major floods using solely observable parameters describing physical characteristics of a basin plus the mean rainfall intensity and mean duration of storms. Results were promising and show that the theory, in addition to its significant scientific value, may be nearly ready to aid in the determination of flood distributions at ungauged sites.

The meeting closed with a panel discussion which reflected upon the papers presented and future research needs and opportunities. The importance of scale to hydrologic problems was discussed. There seemed to be universal agreement that several lines of research were coming to fruition and promised both scientific advances and operationally useful procedures; furthermore, the need to keep in mind these dual purposes for hydrologic research was emphasized. Some research is oriented more toward advancing science and some toward water management concerns. This dichotomy has led to confusion when research, whose aim is to contribute to one of these objectives, is unjustly faulted for failing to contribute to the other. Attempts are being made to make a written summary of the panel discussion available; these can be obtained by writing J. R. Stedinger.

This meeting report was contributed by Jery R. Stedinger, *U.S. Geological Survey, 410 National Center, Reston, VA 22092.*

Multivariate Modeling

The special session entitled Multivariate Modeling of Hydrologic and Other Geophysical Time Series was held during the AGU Fall Meeting in San Francisco on Thursday, December 8, 1983, and was sponsored by the Surface Runoff Committee of the Hydrology Section of AGU. The session brought together about 100 participants from different disciplines, including hydrologists, oceanographers, meteorologists, and statisticians, to discuss the state of the art and new developments of stochastic description and modeling of multiple time series of hydrologic and geophysical phenomena.

The papers and discussion generated during the session covered a wide variety of hydrologic variables such as streamflow, precipitation, specific conductance, groundwater and water use, meteorologic variables such as air temperature, wind and pressure, and oceanographic variables such as ocean temperature and velocity. Among the topics discussed were: modeling that is oriented to data generation of multivariate processes, basic data analysis and description of statistical characteristics in time and space; modeling specifically oriented to forecasting the processes involved; transfer of hydrologic and geophysical information; and detection of changes in hydrologic information.

Positions, questions, and comments made during the panel discussion, in addition to stirring the pot a little bit, served to put several issues in perspective. One issue addressed was model complexity. One of the panelists, who may be the grandfather or perhaps the Godfather of synthetic hydrology, and who, having been present at the creation of some of the concepts about which much was heard and discussed in this special session, questioned whether anything substantial has been done. Is it necessary to have models with so many parameters? Is the information contained in any model or metamodel redundant or useful? Perhaps models in their own metabolism have replaced processes, and we may be modeling models instead of real physical processes. In addition, the ease of computation may have lead us to worry too much about micro-procedures. This may be regretable, and a need for philosophy and new language may be in order. Some other panelists appeared to agree with the foregoing points, although more cautiously.

It has been about 20 years since the univariate AR(1) model was first suggested for modeling hydrologic processes; it has been about 15 years since the multivariate AR(1) model was suggested for modeling multisite processes; it has also been about 15 years since the ARMA models have become popular for modeling series of natural phenomena; and it has been about 10 years since the disaggregation model was first introduced in hydrology. Hence, it is not too surprising that the majority of the papers presented in the session reflected the experience gained during the last 10 years and the efforts to overcome some of the shortcomings inherent in some of the "traditional models and approaches." For instance, there were lengthy discussions on the subject of models with parsimony in the number of parameters, both for the direct multivariate models as well as for the disaggregation models. It is now clear that simple multivariate models retain the necessary flexibility of reproducing the basic properties shown by most annual time series of geophysical phenomena. Likewise, it is now clear that the major shortcoming of disaggregation models (i.e. the large number of parameters) may be overcome by step disaggregation, a scheme with a minimum number of parameters that preserves the needed covariances and additional property. These procedures certainly have addressed the question of model complexity, redundancy, and parsimony which was put forward during the panel discussion.

Other points raised during the panel discussion include the following questions: Does anyone care about modeling and generation anyway? Is it really better to use synthetic samples than to use historical records alone? How would designers react to designs made from synthetic hydrology if these designs deviate significantly from those derived by conventional activities or those derived by simply looking at history? Could one not select a model which supported one's prior inclinations? Has synthetic hydrology produced design suggestions well outside the limits proposed by historical records and conventional techniques? If so, have they been "explained away" or simply ignored as being mere artifacts of the random number generator?

Certainly we wish we could have answers to the foregoing questions, but any one answer will not please everyone concerned and will be controversial. Synthetic hydrology has been useful for considering various long-term assessments associated with sequences of flows. Documented studies have been made on the subject not only in the United States and Canada but in other countries as well. However, these issues, although quite important, were not discussed in the special session. The main purpose of the session was to discuss the state of the art and new developments in modeling multiple time series of hydrologic and other geophysical phenomena. Perhaps it is now time to think and plan another meeting in the future to discuss more specifically the foregoing questions.

In summary, the special session served to identify some of the shortcomings of the traditional modeling techniques and the ways to circumvent them. It served to indicate how multivariate modeling of certain types of hydrologic processes such as annual streamflow may be effectively done with models that are simple, while modeling of periodic processes such as short-term precipitation as well as short-term meteorological and oceanographic events are more complex due to the extreme variability they often exhibit and due to the inherent irregular and gapps data bases which are available. The session also served to put some other relevant issues under perspective, such as those related to measuring the benefits of forecasts and evaluating and documenting the real usefulness of multivariate modeling techniques in the realm of practical decision making.

The exact titles and the abstracts of the papers may be found in *Eos*, Nov. 8, 1983. Interested readers should write to the authors for copies of the papers. On behalf of the Surface Runoff Committee of the Hydrology Section of AGU, the session organizer wants to express his deep appreciation to all session participants for making this, along with the flood sessions, one of the best stochastic hydrology meetings in a number of years.

This meeting report was written by Jose D. Salas, *Associate Professor of Civil Engineering, Colorado State University, Fort Collins, CO 80523.*

Article (cont. from p. 321)

Geochemical Reservoirs

On the basis of samples from many locations in the oceans, it is widely (but by no means universally) assumed that the oceanic lower crust resembles the base of obducted ophiolite sequences. For continental lower crust, however, we know only a few possible examples, represented by high grade granulite terrains and by xenolith suites from volcanic pipes. Hence, the physical properties, compositional constraints, and scale of heterogeneity of the lower continental crust are poorly known.

Plate tectonics models suggest a long evolutionary history and probably great diversity. Do isotopic ages determined for the lower crust represent true ages of rock units? Do ages match the oldest overlying upper crustal rocks, or have they been successively reset during additive processes from the upper mantle or from lateral subduction? The more mafic compositions of the deep crust postulated from seismic velocity data are difficult to reconcile with the silicic-to-intermediate gneisses seen in possible exposures of deep crustal rocks.

Major questions related to the composition and evolution of the upper mantle can be approached through xenolith research, but, again, there are more questions than answers: Are geotherms, derived from the equilibrium assemblages of peridotites and eclogites, transient phenomena related to mantle diapirism and kimberlite genesis? Are inflections in geotherms real? Are they related to thermal boundary layers? Are kimberlites produced by diapirs? Why are other magmas not produced with them? What are the scales of lateral and vertical heterogeneities implied by the varied xenolith suites in single pipes or localized groups of pipes? What are the mechanisms and kinetics of the widespread metasomatism of the uppermost mantle that is evident in composite or veined xenoliths and is required by several models of basalt genesis? Are isotopic ages of xenoliths apparent or real? Is suboceanic mantle different in composition from subcontinental mantle? What is the Mohorovicic discontinuity?

Fluxes of materials through subduction zones are crucial to the evolution of the lithosphere-mantle system but are poorly understood. It is widely believed that subduction zones are the loci of generation of new continent crust, but every link relating subducted lithosphere to continental crust is still seriously debated. Important uncertainties include the source of island arc magmas, the sources of their trace elements, the average composition of island arcs, the nature and degree of reworking of mature island arcs, the average composition of continental crust, and the relationship of the latter to island arc composition. Isotopic studies now suggest that ancient recycled oceanic crust and lithosphere may play an essential role in the production of modern mid-ocean ridge basalt (MORB) as well as ocean island basalts. The possibility that modern basalts are windows to ancient recycled crusts bears upon numerous aspects of mantle reservoirs and evolution and on the kinematics of the subduction process itself. Furthermore, the synchronous appearance of volcanic activity over wide areas, both intraplate and at margins, suggests magmatic processes that may have only an indirect relation to the movement of plates.

The number, size, and spatial arrangements of major geochemical reservoirs capable of yielding distinctively different magmas are a subject of vigorous debate. Several very different models are advocated. One general type postulates a primitive lower mantle, an enriched layer (at the top or the bottom of the mantle), and variously enriched or depleted heterogeneities scattered through the mantle. Another requires continuing chemical exchange between the mantle and core and between the upper and lower mantles. In still other models the main magma reservoirs are in the upper mantle; the lower mantle is the depleted crystalline residue from early earth differentiation (Figures 4 and 5).

Information on the nature and magnitude of fluxes between reservoirs is essential to an understanding of the chemical and differentiation history of the earth. The nature, thickness, and origin of subcontinental lithosphere and its relationship to the overlying crust are subjects of widely divergent hypotheses, ranging from the view that its base is a thermal boundary layer directly analogous to oceanic lithosphere to the view that it is chemically distinct, thick, and a major reservoir of incompatible trace elements.

Oceanic island and ocean ridge basalts have recently been interpreted as having geochemical signatures of recycled ancient oceanic crust, raising anew the question of whether the differentiation of the mantle has proceeded irreversibly or is approaching a steady state with recycling. Oceanic island volcanic rocks are distinctly more enriched in incompatible trace elements than are mid-ocean ridge basalts. A widely accepted model assumes that the global extent of these latter rocks implies a mantle layer of global extent as a source, but the isotopic data, especially of helium, lead, and neodymium, indicate that this source must be heterogeneous. However, the measurement of rare gases, particularly $^3He/^4He$, shows that recycled oceanic crust is unlikely to have been a the major contributor to at least some oceanic island basalts.

The mantle apparently contains substantial quantities of volatiles, some of which give evidence of being primordial (^3He, ^{129}Xe). Components such as H_2O and CO_2 may be recycled from crustal materials. Once introduced into the mantle, these volatiles will play a profound role in mantle magmatism, as shown by experiments with systems containing variable CO_2/H_2O ratios. Volatile transport in the mantle has been invoked as a mechanism to produce mantle metasomatism as a precursor to the production of basaltic liquids.

It appears unlikely that the current tectonic regime could have come into being on a totally pristine, undifferentiated earth. The formation of the earth by accretion was clearly a violent process, which probably involved extensive melting and stirring related to core separation, thermal convection, and convection driven by chemical bouyancy differences. The end product could have been a layered or homogeneous mantle, and any early formed crust may have been either thick or thin, buoyant or gravitationally unstable, and with very low or moderate abundances of the incompatible elements. However, an initially thick buoyant crust of basalt would have transformed into dense eclogite at its base as the mantle cooled. Thus, an initially buoyant crust could have converted to a dense, unstable crust with time. Such a process could destroy the early geological record.

Even if a form of plate tectonics began very early in earth history, other tectonic processes are likely to have been important. A magma ocean may have formed, as suggested by analogy with lunar history, or indeed the moon itself may have formed from the earth, altering the earth's geochemical inventory. The widespread current magmatism, combined with evidence that the earth has been cooling, also suggests that an extensive molten upper mantle existed in early earth history. Could such an upper mantle cool without forming cumulate layers and hence chemical stratification?

Controversy exists as to whether the two largest discrete reservoirs, the core and the mantle, were ever in equilibrium with each other. The state of oxidation of the mantle, as currently postulated, is incompatible with equilibrium. The upper parts, and possibly the entire mantle, may be contaminated by subducted and recycled crustal materials, particularly water. Thus, the presumed high oxidation state of the upper parts of the mantle may be an artifact of the subduction process. In any case, the high nickel content of the upper mantle seems to preclude equilibration with the core.

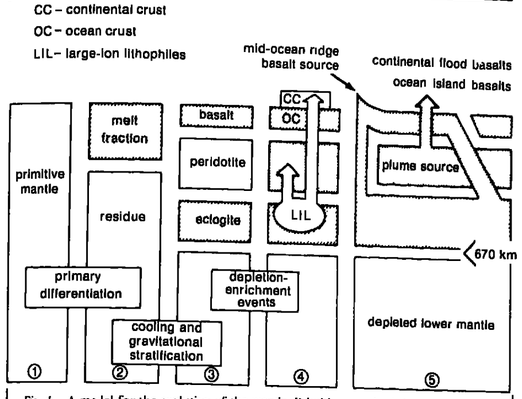

Fig. 4. A model for the evolution of the mantle. Primitive mantle (1) is partially molten either during accretion or by subsequent whole mantle convection which brings the entire mantle across the solidus at shallow depths. LIL elements are concentrated in the melt. The deep magma ocean (2) fractionates into a thin, plagioclase-rich surface layer and deeper, olivine-rich and garnet-rich cumulate layers; (3) late-stage melts in the eclogite cumulate are removed (4) to form the continental crust (c.c.), enrich the peridotite layer, and deplete MORB's, the source region of oceanic crust (o.c.), and the lower oceanic lithosphere. Partial melting of the plume source (5) generates continental flood basalts (CFB), ocean island basalts (OIB) and other enriched magmas, leaving a light, depleted residue. (Source: Reprinted from D. L. Anderson, *Science, 213*, 82–89, 1981 with permission.)

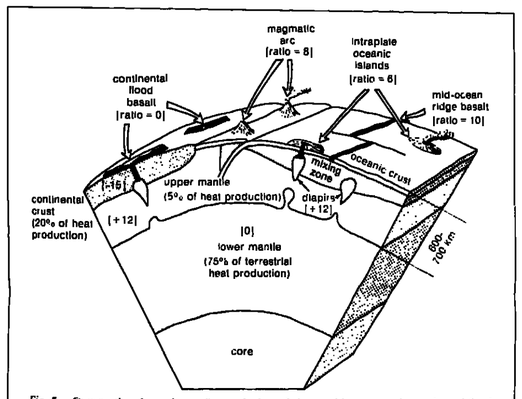

Fig. 5. Contrasting hypotheses for evolution of the earth's crust and mantle and for location of geochemical reservoirs. Figure 4 suggests a complex history of early earth differentiation leading to a depleted, inert lower mantle and a geochemically active upper mantle. A different model, from DePaolo, also emphasizes an active upper mantle, but shows plumes originating as diapirs from the lower mantle. (Source: Reprinted from D. J. DePaolo, *Eos Trans. AGU, 162*, 137–140, 1981.)

Plate Tectonics Through Time

Identification of plate tectonics processes in the past depends on the assumption that we can read from the geological record the evidence that has been produced by these processes. The current assumption that continental crust cannot be subducted is yielding to contrary geological and geophysical evidence indicating a doubling of continental crust by underthrusting beneath some mountain systems. The possibility remains, however, that observed crustal thickening is the result of squeezing of two continental masses together, with minimal underthrusting. Will it be possible to distinguish between these two types of collisions in deeply eroded ancient continental crust? Recent observations from deep seismic and electrical soundings suggest that this may indeed be possible.

In a presently active collision zone, such as that represented by the Alpine system and the Himalayas, opportunities exist for examining young and continuing orogenic phenomena. In addition to geological mapping and seismic and electrical methods of deep exploration, heat flow studies, and applications of modern space geodetic equipment to observations of ongoing deformation should be highly productive. Modern collision areas may also yield clues to the nature of ancient continental terrains such as the Hercynian and Grenville, where plate tectonics has provided no convincing model for understanding vast terrains characterized by complex deformation, uniformly reset ages, and a very thick crust. The apparent fragmentation of eastern Asia under the impact of the advancing Indian subcontinent may also provide a model for the generation of crustal fragments such as those now being recognized as allochthonous terrains in many orogenic areas.

From the study of plate motion averaged over several million years, we have learned much about the style of plate tectonics, have confirmed the usefulness of the hypothesis that plates behave rigidly on this time scale, and have formulated models to explain the cause of their motion. In the coming decade we should focus on the style of plate tectonics over time scales both much longer and much shorter than several million years. For time scales of 10–100 m.y., individual plates appear to have episodes of constant motion, separated by major changes in direction and velocity. Changes in direction of motion of plates with respect to hot spots appear to be consistent with simple models in which plates are pulled to their subducted slab boundaries and pushed by their spreading ridge boundaries. Velocity is greater for plates with a large fraction of their boundaries attached to down-going slabs. It is important to test critically whether these generalizations hold for all Cenozoic and Mesozoic plate motions and especially whether the change in plate boundaries causes a change in plate directions and velocities, or vice versa. Because present seafloor has been formed since the breakup of Pangea and because continental hot spot tracks are difficult to recognize, the primary source of information on pre-Jurassic plate motions will be paleomagnetic data combined with accurate age dating. We do not yet know whether plate tectonic regimes are episodic on time scales longer than 100 m.y. Among many other unanswered questions are these: Was the episode of plate motions and continental drift prior to the breakup of Pangea preceded by a long quasi-static interval of little or no continental drift on an earth with just one continent? Is the apparent polar wander of the major continents before the breakup of Pangea the result of plate motion or of true polar wander?

Almost nothing is known about episodicity of plate motion on a time scale of years or decades. A ratchet mechanism clearly operates to hold plates locally fixed by friction at active margins until the strength of crustal rocks is exceeded; the resulting rupture causes local movement and devastating earthquakes. Occasional displacement inputs are large (tens of meters and greater), and plate movements are small (a few centimeters per year). Thus, the superposition of strain events may contribute significantly to plate movements. Near active margins, crustal movements are highly inhomogeneous in space as well as time. Creep rates determined across various parts of the boundaries are both smaller and larger than those predicted by existing plate models. New geodetic techniques are able to monitor plate movement and deformation over baselines hundreds or thousands of kilometers in length and are now being used for essentially continuous measurement of the relative and absolute motion of the Pacific, Nazca, North American, South American, Australian, and Eurasian plates. The accuracy of these measurements is a few centimeters, so it will be on the order of a decade before meaningful velocities will be available.

Intriguing aspects of volcanism have been noted which seem to require major perturbations of the plate tectonics model. Evidence has been presented that volcanism is strongly episodic and that certain pulses have been synchronous over wide regions, including marginal orogenic belts, intraplate hot spots, and continental rifts. If true, the factors governing volcanism must be global and unrelated to local conditions such as rates of subduction or seafloor spreading. Of particular interest are the production rates of volcanism necessary to generate the elevated plateau regions of the Pacific and the extensive Cretaceous episode of volcanic activity thought to have occurred in the interior of the Caribbean and in the central and western Pacific Ocean.

Vertical tectonic movements, though less spectacular than horizontal motions, can be easily observed and are clearly episodic on various time scales. The gradual subsidence of passive continental margins through time can be modeled as a response to the loss of heat. But what about the interior regions of the continent? Episodic subsidence of basins and elevation of domes within continents are well known, whereas other cratonic areas appear to have been extremely stable. Are there processes occurring at the crust-mantle boundary, causing continental thinning or thickening which would, in turn, produce elevation changes at the surface of the continents?

It appears that all plates, spreading ridges, and trenches are in relative motion. Therefore, none of these features can serve as a fixed reference frame. The spin axis provides the only widely accepted "absolute" reference frame. Assumptions of past positions of the spin axis come largely from magnetic data and from determinations of the positions of ancient equators by geological analysis of deep-sea drilling cores and by analyses of paleoclimatic indicators. The apparent polar wander paths of major continents have been determined for substantial portions of the Phanerozoic. With this information it has been possible to test independently the accuracy of seafloor spreading reconstructions and to estimate the rates of continental drift with respect to the spin axis.

However, the assumption that plate motion with respect to the spin axis is identical to plate motion with respect to the mantle can be challenged if true polar wander has occurred. If true polar wander is to be established, absolute reference frames other than the spin axis must be defined. Proposed reference frames include hot spots based on the assumption that hot spots originate in the lower mantle; and mathematical reference frames that minimize the motion of the lithosphere or minimize the motion of ridges and trenches. For shorter periods (years and decades) the inertial reference frame and a fixed star reference frame can be defined from satellite and astronomical data. When applied to plate motions over the last few million years, all of these reference frames have been found to be similar, the differences being on the order of one tenth of a degree per m.y. An important emerging problem is to determine whether the small differences between reference frames are significant.

Ninety Years of Progress

Charles L. Drake puts in perspective the problems with which we are struggling today. His essay highlights the 1892 Presidential address by Grove Karl Gilbert to the Geological Society of America as a reference point to important geological problems of 90 years ago. It is a bit dismaying to note that many of those same problems are still with us. His closing remark ". . . if we are optimists, we may be comforted by the reflection that geologists of this generation, at least, will have no occasion, like Alexander, to lament a dearth of worlds to conquer," is equally appropriate today.

News

Eagleson Voted President-Elect

Peter S. Eagleson

Peter S. Eagleson, professor of civil engineering at the Massachusetts Institute of Technology, was chosen AGU President-Elect, according to a report from the AGU Tellers Committee on the recent elections. The Tellers report will be formally presented to the AGU Council at the Spring Meeting in Cincinnati on May 15.

Peter M. Bell, of the Geophysical Laboratory of the Carnegie Institution of Washington has been elected AGU General Secretary. He succeeds Leslie H. Meredith. Juan G. Roederer of the Geophysical Institute of the University of Alaska, Fairbanks, will succeed Carl Kisslinger as Foreign Secretary. The 4-year terms for the general secretary and foreign secretary end June 30, 1988.

The Tellers Committee reports that 3,964 valid ballots—24% of the 16,496 ballots mailed—were received by the March 30 voting deadline. A list of the "write-in" votes will be given to the next nominating committees.

The results of the section elections are listed in Table 1. The new section officers will serve AGU from July 1, 1984, through June 30, 1986. Each section president-elect will serve 2 years in that capacity and then serve 2 years as section president. They will be voting members of the AGU Council for all 4 years.

On July 1, the following section presidents-elect will assume 2-year terms as section presidents:

Atmospheric Sciences, Fred D. White; Geodesy, Byron D. Tapley; Geomagnetism and Paleomagnetism, Neil D. Opdyke; Hydrology, R. Allan Freeze; Ocean Sciences, Joseph L. Reid; Planetology, Laurene A. Soderblom; Seismology, Lynn R. Sykes; Solar-Planetary Relationships, George C. Reid; Tectonophysics, Thomas J. Ahrens; Volcanology, Geochemistry, and Petrology, G. Brent Dalrymple.—*BTR*

TABLE 1. AGU Section Election Results

Section	President-Elect	Secretary
Atmospheric Sciences	Ralph J. Cicerone	Rex J. Fleming
Geodesy	John D. Bossler	James G. Marsh
Geomagnetism and Paleomagnetism	Subir K. Banerjee	John W. Hillhouse
Hydrology	Marshall E. Moss	Thomas Maddock III
Ocean Sciences	Arnold L. Gordon	Barbara M. Hickey
Planetology	Sean C. Solomon	Raymond E. Arvidson
Seismology	Stewart W. Smith	William L. Ellsworth
Solar-Planetary Relationships	R. A. Helliwell	G. G. Sivjee (Aeronomy); Leonard F. Burlaga (Cosmic Rays); George K. Parks (Magnetospheric Physics); Bruce T. Tsurutani (Solar and Interplanetary Physics)
Tectonophysics	Richard P. Von Herzen	Barry Parsons
Volcanology, Geochemistry, and Petrology	P. Robin Brett	Bruce D. Marsh

New Climate Delivery System Developed

The Illinois Climate Center can now provide information through the Climate Assistance Service (CLASS) about the current status of many weather parameters, such as accumulated degree days, differences between seasonal rainfall and normal, and long-range future climate predictions. Illinois is the first state to start such a near real-time climate information system where the observations are gathered from National Weather Service cooperative observers.

The concept of CLASS was envisioned and designed by Stanley Changnon, chief of the Illinois State Water Survey; Wayne Wendland, head of the Climatology and Meteorology Section; and John Vogel, head of the survey's Climate Information Unit. Grants from the Illinois Department of Energy and Natural Resources and from the National Oceanic and Atmospheric Administration (Climate Analysis Center and National Climate Program Office) were coupled with existing Survey funds and information products of the Illinois State National History Survey to develop this system.

The Illinois Water Survey developed a plan for a Climate Information Center for Illinois 5 years ago. This center now gathers most to the state's natural resource data on weather and climate into its computers. By late 1984, anyone in Illinois will be able to obtain data and information rapidly that before were difficult to obtain sooner than 1 or 2 months after the fact. Complex information about the state's vast atmospheric resources will be generated. Currently, only state agencies are accessing the data and information in a user test.

CLASS will be usable by a variety of interests, which follow: (1) Agricultural interests can access growing degree day information for major crops, information on insect pest outbreaks, and soil moisture measurements for planting and irrigation decisions. (2) Energy interests can plan and monitor coal, gas, and oil supplies by accessing information on heating degree days in winter and cooling degree days in summer. (3) Transportation concerns can monitor extremes of temperature, percipitation, ground frost, and snowfall to plan for repairing roads and highways. (4) Water resources managers can monitor precipitation accumulations and predictions to manage water systems better. (5) Air and water quality regulators can monitor the evolving conditions that affect water quality such as prolonged deficiences of rainfall or air stagnation. (6) Those concerned with natural resources including conservationists can monitor the general status of basic atmospheric conditions, including extremes of temperature, snowcover, or drought events which have detrimental effects on the flora or fauna of the state.

This news item was submitted by Stanley A. Changnon, John L. Vogel, and Wayne M. Wendland *from the Illinois State Water Survey, Champaign, Ill.*

World's Carbon Budget: Sinks and Sources

Interest in natural and man-made carbon dioxide production is stirred because it resides after formation in critical atmospheric zones. To determine the oncoming "greenhouse" effect, indeed to determine whether there will be a greenhouse effect, investigators have tried to sum up the global carbon cycle. In accounting for the sources and sinks of carbon dioxide produced at the earth's surface, it has been postulated that most of the unbalanced sources can be identified with the earth's biomass and not so much with man's combustion of fossil fuels (*Ecol. Monogr., 33,* 235, 1963). New figures on the calculated areas of tropical forests suggest otherwise.

S. Brown of the University of Illinois Department of Forestry and A.E. Lugo of the Institute of Tropical Forestry, Rio Piedras, Puerto Rico, calculated values for the total biomass as 205 x 10^9 tons. They determined weighted biomass densities for undisturbed closed and open broad leaf forests as 176 and 61 tons per hectare. To quote their recent report: "These values are considerably lower than those privately reported and raise questions about the role of the terrestrial biota in the global carbon budget" (*Science, 223,* 1290, 1984).

The question is an important one. If the release of carbon dioxide to the atmosphere can be assessed correctly, it may be possible to reduce the total amount. Conceivably, a reduction may not delay the consequences of a global mean temperature rise, but there are many unknowns in determining the proportions. A critical factor may be assessment of the contribution to global carbon dioxide from the biota. It is believed that recent imbalances in the carbon budget have resulted from changes in tropical forest regions.

Deforestation along the equatorial belt results in burning or produces large volumes of decaying biomass, both of which yield carbon dioxide in the process. Problems arise in estimating the tonnage of biomass, as well as the amount of deforestation. There are many factors, such as wood density and forest expansion and productivity, that are difficult to estimate.

Brown and Lugo noted that the data base available for making estimates of the biomass is limited. Instead they calculated the carbon pool in tropical forests from data on the volumes of standing timber extending over a large area, which included 97% of the tropical belt area. The result is that the global carbon budget could be balanced after all.—*PMB.*

Year of Ocean

A national celebration of the oceans and their products will begin July 1 when the "Year of the Ocean" officially opens. A preliminary kickoff reception was held in March. The goal of the celebration is to increase awareness of the importance of the oceans.

"It is vital that we now look toward finding workable solutions to the vast and varied issues surrounding the wise use and management of our seas," said John V. Byrne, administrator of the National Oceanic and Atmospheric Administration (NOAA) and chairman of the board of the Year of the Ocean Foundation. The foundation includes public and private organizations.

"The time is right to initiate new activities and reawaken Americans to the tremendous potential of this great resource," he added. "The Year of the Ocean will act as a springboard to increase awareness and understanding of our treasured oceans and act as a neutral forum for shared goals and objectives among ocean users."

To help meet these objectives, nearly one dozen roundtable discussions will be held among those working on the ocean in academia, industry, and policy making, according to Diane C. Boratyn, national coordinator for the celebration. The roundtables will be designed to facilitate collaboration among leading ocean users and policy and decision makers to raise, examine, and recommend resolutions on topical ocean issues.

Ocean Day, slated for July 1, will open the celebration, which will continue for 1 year with activities sponsored by the federal government, industry, state and local governments, academia, and ocean organizations. A five-part television special series also is being planned.

For additional information, contact Boratyn, Box 1100, 3421 M Street, N.W., Washington, DC 20007 (telephone: 202-333-1188).

CO_2 and Sea Level

There is considerable discussion currently about the potential effects of carbon dioxide build-up in the atmosphere over the next several decades. The sources of information are two Government funded reports, one by the National Research Council (NRC), the other by the Environment Protection Agency (EPA), both were released within the last five months. The reports were described recently as being conservative, although the consequences of the resulting greenhouse effects are deemed inevitable. Atmospheric warming on a global scale of as much as 5°C cannot be avoided, only perhaps delayed by a few years at best (*Environ. Sci. Technol., 18,* 45A-46A, 1984). The cause is the burning of fossil fuels. Oil will not be too important because its supplies are predictably exhausted on the time scale of 50–100 years. Coal burning is considered as the main source of carbon dioxide. Among the more spectacular results of a global temperature rise over the next 100 years is the expected rise in sea level of a minimum of 70 cm (*Oceanus,* Winter, 1983/84). If the West Antarctic Ice Sheet breaks up and melts, the rise could be in the several meter range. Sea level rose only 15 cm in the past century.

An example of the sea level rise in Boston, MA, was given by T. C. Schelling of Harvard University (*Oceanus, op. cit.*). If unattended, Boston and Cambridge, Massachusetts would be essentially inundated. The answer in this instance would be the construction of dikes, much as been done for a long time in Holland. This, and other examples of sea level rise and warming effects set the tone of not being too serious if viewed on a 100-year time scale. Man can adjust and adapt.

The EPA study is pessimistic about changing the inevitable trend. The NRC study sees no cause for sudden alarm, but recommends detailed studies. One of the so far unevaluated factors is the contribution from gases other than carbon dioxide. Other "greenhouse gases" include nitrous oxide, methane, and chloro- and fluorocarbons.—*PMB*

Geophysicists

Roger R. Revelle, an oceanographer, population scientist, and professor of science and public policy at the University of California at San Diego, will be presented with the fifth Vannevar Bush Award by the National Science Board (NSB), the 25-member policy-making body of the National Science Foundation, at the board's annual dinner on May 9. The award is presented from time to time to acknowledge outstanding contributions in science and technology that are particularly significant to the national welfare. In announcing the award, NSB Chairman Lewis M. Branscomb said, "Professor Revelle's career has long been devoted to the conviction that science can make a great contribution to the welfare of people everywhere—especially the poorest people. His work is known and admired by people all over the world, and is a living demonstration that science and humanism can be natural companions." Revelle, an AGU Fellow, was director of the Scripps Institution of Oceanography from 1950 to 1964, and was one of the founders of both the Intergovernmental Oceanographic Commission and the Scientific Committee on Ocean Research of the International Council of Scientific Unions.

Chapman Conference on the Magnetospheric Polar Cap

A Chapman Conference on the Magnetospheric Polar Cap will be held August 6–9, 1984 at the University of Alaska, Fairbanks Campus. Conference co-convenors are S.-I. Akasofu and J. R. Kan

This conference will provide a unique opportunity for researchers to discuss various aspects of polar cap phenomena, the magnetotail and the effects of the interplanetary magnetic field. The magnetospheric polar cap—the highest latitude in the upper atmosphere bounded by the auroral oval—has attracted much attention during the last several years. Discussions will emphasize an examination of how polar cap phenomena are controlled by solar wind and the interplanetary magnetic field.

There will be invited reviews and invited and contributed presentations. The Call for Papers was published in the January 24, 1984 issue of Eos. Abstract Deadline is May 1, 1984.

Limited funding is available to support student travel. The deadline date for student travel applications is May 1, 1984. Call AGU to request a travel grant application.

For information on the required abstract format or further meeting logistics, contact:

AGU Meeting Department
2000 Florida Avenue, N.W.
Washington, DC 20009
(202) 462-6903

For program information, contact:

S.-I. Akasofu or J. R. Kan
University of Alaska
C. T. Elvey Building
Fairbanks, AK 99701
(907) 474-7287

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POSITIONS AVAILABLE

Eastern Illinois University/Department of Geography & Geology: Teaching Position in Geology. The Department of Geography-Geology at Eastern Illinois University is accepting applications for a temporary one year position in geology starting August 25, 1984. Chances are very good that this position will become full-time tenure track. A Ph.D. is required. Rank will be at the assistant professor level. The candidate will be expected to teach physical or historical geology. Preference will be given to those candidates who can teach one or more of the following: an introductory course in geophysics, economic minerals, structure, hydrology, and field geology. Other specialties will definitely be considered. If the position becomes permanent, teaching at summer field camp and the pursuit of research will be expected.

The Department has six full time geologists and approximately 120 undergraduate geology majors.

APPLICATION PROCEDURES:

(1) Application deadline is May 31, 1984 (early completion of application is encouraged)

(2) Individuals wishing to apply should immediately make their interest known to:

Dr. Gary Wallace, Chairman
Department of Geography and Geology
Eastern Illinois University
Charleston, Illinois 61920
Telephone: office—(217)581-2626; home—(217)345-3772

(3) Candidates should submit the following materials to the above address as soon as possible.

a] Letter of application
b] A current vita

c) Transcripts from all institutions from where college credits have been earned

d] Arrange for three letters of recommendation to be sent. Send names, addresses, and telephone numbers of referees with letter of application.

Eastern Illinois University is an affirmative action and equal employment opportunity employer.

Software Systems Engineer. Candidate will be responsible for the continuing development, maintenance and improvement of major software systems which form a part of the real-time control, data processing and data recording portions of a state-of-the-art high sensitivity, high resolution radar system used for imaging near earth and deep space satellites. The system involves three general purpose computers (ModComp classics) and two special purpose array processors. The complexity of the system presents a considerable challenge. The person involved should be prepared to assume a strong personal responsibility for the continued improvement and operational reliability of the software systems, and should be prepared to work unusual hours on occasion.

Strong mathematical and engineering or physics background is required as well as a good knowledge of both assembly and FORTRAN computer languages. An appropriate bachelor's degree and at least two years of applicable experience are required. Must be capable of working with limited supervision.

Please write, enclosing resume to:
J.T. Karakat
Assistant to the Director
Haystack Observatory
Westford, MA 01886

MIT is an equal opportunity/affirmative action employer.

Cooperative Institute for Climate Studies/Postdoctoral Fellowship. The Department of Meteorology at the University of Maryland, College Park has established the Cooperative Institute for Climate Studies (CICS) with NOAA to engage in collaborative research. The Institute is involved in a variety of studies oriented toward a better understanding of climate and currently has openings for three postdoctoral fellows to join with the current Institute staff. Details of the areas of study are as follows:

A. *Shortwave Radiation Modeling:* This position will involve research toward the development of a detailed shortwave radiation model and the application of radiative transfer models to the interpretation of radiation observations. Additional research may include radiation studies needed for the interpretation and calculation of the planetary radiation budget from satellites such as the NOAA operational satellites Ninnbus 7 and the forthcoming Earth Radiation Budget Experiment (ERBE).

B. *Earth Radiation Budget Analysis:* This research position involves analysis of the relationship of the general circulation and the atmospheric energy budget to the net radiational forcing utilizing data from numerical analysis-forecast models, general circulation models and satellite observations of the planetary radiation budget. Both theoretical and observational aspects of this important problem will be considered.

C. *Steady-State Climate Modeling:* This position calls for a meteorologist with experience or interest in experiments with steady state climate models. Principal activities will involve running experiments with existing steady state models, deriving careful verification procedures, handling extensive observed data sets, making modifications in model computational schemes for running the models.

Letters of application should be sent to:
F. Baer, Director CISC
Department of Meteorology
University of Maryland
College Park, MD 20742.

Applications should include a curriculum vitae and names of three references. Applications received before May 15, 1984 will receive full consideration.

The University of Maryland subscribes to a policy of equal educational and employment opportunity. The University of Maryland, under Title IX of the Education Amendment of 1972, does not discriminate on the basis of sex in admission, treatment of students or employment.

Air Force Geophysics Laboratory Geophysics Scholar Program (1984–1985). The Air Force Geophysics Laboratory (AFGL) and the Southeastern Center for Electrical Engineering Education (SCEEE) announce that applications are invited for research appointments during the 1984–1985 term in the Geophysics Scholar Program. This program provides research opportunities of 10 to 12 months duration for selected Engineers and Scientists to perform research in residence at the AFGL, Hanscom AFB, near Boston, Massachusetts. Scholars will be selected primarily from such fields as Geophysics, Space Physics, Meteorology, Ion Chemistry, Applied Science, Mathematical Modeling using Computers, and Engineering.

To be eligible, candidates must have a Ph.D. or equivalent experience in an appropriate technical field. Some appointments may be continued (prior to August 1985) or early applications are encouraged. All qualified applicants will receive consideration without regard to race, color, religion, sex, or national origin. Application Deadline for September Appointments, August 1, 1984. For further information and application forms contact: SCEEE, 1101 Massachusetts Avenue, St Cloud, FL 32769 Telephone: (305) 892-4110

SCEEE supports Equal Opportunity/Affirmative Action.

Scientist/Engineer. The Haystack Observatory is seeking a Scientist/Engineer to work in the field of Very Long Baseline Interferometry (VLBI). The Scientist/Engineer would assist in the development of new VLBI data acquisition electronics as well as assist with the processing and analysis of data taken for the NASA Crustal Dynamics Project. The applicant should have a Ph.D. or its equivalent in radio astronomy or a related field. Some engineering knowledge and experience with electronics is needed and a knowledge of computer and microprocessor programming would be an asset.

Please write, enclosing resume, to:
J.T. Karakat
Assistant to the Director
Haystack Observatory
Westford, MA 01886

MIT is an equal opportunity/affirmative action employer.

Electronic Engineer. The MIT Haystack Observatory has an opening for an Electronic Engineer to design and develop electronic equipment for Radioastronomy and Very Long Baseline Interferometer (VLBI) measurements for radio astronomy and geodetic applications. Duties include design and construction of RF systems using mixers, cooled paramps or maser amplifiers, as well as IF systems, frequency multipliers, PPLS synthesizers, detectors, etc. Person will supervise construction, test and integration of such new equipment and document all new equipment thoroughly. Engineer will occasionally participate in observations experiments with scientists.

Applicants should have a B.S. in Electrical Engineering or Physics and M.S. or equivalent is desirable but not mandatory. Person should be familiar with the design of microwave circuits involving waveguide and associated components. To a good base grounding in theory of amplifiers, mixers, modulation and noise, etc. should be added the principles of solid state and digital circuit design. Two to five years relevant experience is desirable, but a promising new graduate will be considered if there is reasonable applicable hardware experience during or before school. Ability to work well with others is essential. Previous interest in astronomy is beneficial but not required.

Please write, enclosing resume, to:
J. T. Karakat
Assistant to the Director
Haystack Observatory
Westford, MA 01886

MIT is an equal opportunity/affirmative action employer.

University of East Anglia/Lectureship in Geophysical Fluid Dynamics. Applications are invited for a "New Blood" lectureship in the School of Mathematics and Physics. The envisaged field of research is ocean-ice interaction relevant to the dynamics of the marginal ice zone. Preference will be given to applicants with research experience in geophysical fluid dynamics or ice-floe dynamics or dynamical oceanography. Salary will be on the scale of £7190 to £11825 per annum (under review) plus USS benefits.

Applications (three copies) which should contain a full curriculum vitae, including exact date of birth, together with the names and addresses of three persons to whom reference may be made, should be lodged with the Establishment Officer, University of East Anglia, Norwich, NR4 7TJ, not later than 14 May 1984. No forms of application are issued. In naming three referees you are particularly requested to give only the names of those who can immediately be approached.

GEOPHYSICIST

Faculty position in Seismology/New Mexico Tech. New Mexico Institute of Mining and Technology invites applications for a tenure-track position in Seismology at the Assistant Professor level. The PhD is required. The position is a joint appointment with the College Division and the Geophysical Research Center in the Research and Development Division. New Mexico Tech has had Institutional and research programs in Geophysics for 3 decades, and confers BS, MS, and PhD degrees in the field of Geophysics. Much of the geophysical research has been, and continues to be, related to the determination of the physical characteristics of the Rio Grand Rift a major continental rift in which Tech is located. We currently operate a 14 station seismograph network (jointly with the U.S.G.S.), as well as a 3-component long-period station. In addition, studies of the crust and upper-mantle structure are underway with portable seismograph systems using both earthquake and explosive sources. The geophysics staff and instructional program are part of the 18-member Geoscience Department, which also includes the disciplines of Geology, Geochemistry and Hydrology. The instructional and research activities of the Department are strengthened substantially by professional staff in the New Mexico Bureau of Mines and Mineral Resources, and by support groups in the Research and Development Division. In addition, several of the Tech staff have collaborative research projects with personnel from the nearby Sandia National Laboratory (Albuquerque) and Los Alamos National Laboratory. Send letters of application, resume, and a brief description of teaching and research interests to: Allan R. Sanford, Geoscience Department, New Mexico Tech, Socorro, NM 87801.

Equal Opportunity/Affirmative Action Employer.

Staff Opportunity: Geophysical Laboratory/Carnegie Institution of Washington. Privately endowed, basic-research and educational organization seeks outstanding scientist with broad interest in developing the principles of Element Concentration.

Applicant background especially should include experimental experience involving a wide range of pressures and temperatures, theory of mass and heat transport, and field aspects of ore deposits. Familiarity with stable-isotope research desirable. Creative and innovative qualities essential.

Successful applicant will be appointed Earth Sciences Research Scholar for a period not to exceed three years. After demonstration of leadership and excellence in research, the Scholar will be eligible for a regular staff position. Modest funds are available for technical support of the Scholar's work.

Applications are being accepted by the Director, Geophysical Laboratory, 2801 Upton Street, N.W., Washington, D.C. 20008. Submit 3–5 page summary of proposed research program, curriculum vitae, three letters of recommendation from persons chosen by applicant, and completed Application Form obtainable from Executive Secretary. Starting date is after 1 July 1984 and is negotiable.

The Carnegie Institution of Washington is an equal opportunity and affirmative action employer.

Faculty Position/University of Montana. The Geology Department of the University of Montana is seeking applications to fill a tenure-track, entry-level position at the Assistant Professor level to start as per mid-September 1984 to early June 1985. This position involves replacement of a faculty member on sabbatical leave. Ph.D. in geology is preferred; however, M.A.'s with teaching or professional experience will be considered. Students planning to complete their Doctorate during the 1984–85 academic year are encouraged to apply. Teaching responsibilities include undergraduate courses and introductory geology, mineralogy, petrology, sedimentary, and a seminar in area of special interest.

Those interested should send a letter of application, resume, three letters of recommendation to: Arnold J. Silverman, Chairman, Department of Geology, University of Montana, Missoula, MT 59812. The DEADLINE for applications is May 15, 1984.

The University of Montana is an affirmative action/equal opportunity employer.

Assistant Professor Position/Theoretical Physics. The Physics Department at the University of Houston expects to fill several tenure track positions in theoretical physics at the assistant professor level. The first of these may be filled in the fall of '84. The areas of interest are Condensed Matter, Nuclear Physics, Plasma Physics (including Space Plasmas) and Statistical Mechanics. Our intention is to emphasize interdisciplinary activity within these broadly defined areas. It is desirable that candidates have an interest in interaction with other members of the theory group and the experimental programs.

Send resumes and three letters of reference to George Reiter, Physics Department, University of Houston, Houston, TX 77004.

The University of Houston is an equal opportunity/affirmative action employer.

Mineralogy/Department of Geology, University of Oregon. A position of Visiting Assistant Professor of Geology will become available on September 15, 1984. The successful candidate should have research interests in the general field of mineralogy and crystallography and will be required to teach the universal mineralogy course to geology majors. Teaching of one or more courses in specialized areas of mineralogy is encouraged.

Departmental research facilities of interest to a mineralogist include UV-IR spectrophotometers, electron probe, SEM, neutron activation analysis, AA, XRF, XRD, and a high-resolution X-ray emission spectrometer.

Applicants should have a doctoral degree or have substantially completed the requirements for it before taking up the appointment. Send curriculum vitae, bibliography, and statement of research interests, with names of three professional referees by May 15, 1984 to Chairman, Mineralogy Search Committee, Department of Geology, University of Oregon, Eugene, Oregon 97403.

Salary dependent on qualifications.

The University of Oregon is an Affirmative Action/Equal Opportunity Employer and complies with Section 504 of the Rehabilitation Act of 1973.

University of Wisconsin-Milwaukee Faculty Position in Atmospheric Sciences. The atmospheric sciences program in the Department of Geological and Geophysical Sciences will have a tenure track position supported by state funds at the assistant professor level starting in September 1984. The applicant must have a PhD in meteorology or atmospheric science or a related field. Preference will be given to those who have a good publication record and/or postdoctoral experience. The successful applicant will be expected to develop a strong research and graduate program, and to teach undergraduate meteorology courses starting at freshman level. In the undergraduate major area, he or she will teach courses in advanced dynamics, mesometeorology and mesoscale modeling, in addition to courses related to the field of expertise. Usually two courses (6 credit hours) are assigned per semester.

Research opportunities at UW-Milwaukee include satellite meteorology, severe storm dynamics and energetics, diagnostic modeling, large-scale circulations and energetics, synoptic meteorology and numerical modeling. Research facilities include McIDAS, Great Lakes Research Facility, Urban Research Center, and a rural field station. Interested candidates should forward their resume to: Professor D.-L. Sklar, Chairman, Search Committee, Department of Geological and Geophysical Sciences, UW-Milwaukee, 1900 E. Kenwood Blvd., Milwaukee, WI 53211, with three letters of recommendation from professors and scientists well acquainted with the applicant's education background and research potential. Closing date for applications is 21 May 1984.

UWM is an affirmative action/equal opportunity employer.

Postdoctoral in Field of Planetary Atmospheres. Start summer '84 for 12-month appointment, probably renewable. $17,500. Preferred research interests: Jupiter atmosphere aeronomy (ozone), climate modeling, radiative transfer. Send vitae to: Professor J.W. Chamberlain, Space Physics and Astronomy, Rice University, P.O. Box 1892, Houston, TX 77251.

Old Dominion University/Physical Oceanographer. The Department of Oceanography seeks candidates for a newly created tenure track faculty position. Of particular interest are scientists with experience and/or interest in both field work and geophysical fluid dynamics. The successful candidate will interact with an ongoing observational program and should show strong potential for developing his/her own graduate teaching and funded research programs. ODU is a state-supported university, and the growing Oceanography program currently has 15 faculty and 70 graduate students. Although we anticipate hiring at the Assistant Professor level, scientists with more experience are encouraged to apply. Salary will be commensurate with experience. A Ph.D. is required. Applicants should submit a curriculum vita by June 30, 1984 to: Dr. Donald R. Johnson, Search Committee, Department of Oceanography, Old Dominion University, Norfolk, VA 23508.

Old Dominion University is an affirmative action/equal opportunity institution.

Postdoctoral Fellowship in Experimental Petrology at UCLA. Available September 1, 1984. Candidates should be accomplished in thermodynamics and in synthetic phase equilibria at low and high pressures; knowledge of X-ray crystallography, electron microprobe spectroscopy and field occurrences of ore-forming minerals also required. Please send vita, short summary of research goals, and two letters of recommendation by June 15, 1984 to: W.G. Ernst, University of California, Department of Earth and Space Sciences, Los Angeles, California 90024.

UCLA is an affirmative action/equal opportunity employer.

Instrumental Analyst/UCSC. (Staff Research Associate III, Job #84-0513) Full time permanent. Duties: Management of automated NRF Spectrometry Lab. Duties include equipment maintenance, joint responsibility for calibration and quality control, system development and instruction of users. Opportunity exists for personal research. Requires BS in natural science and two years relevant experience or MS. Spectroscopy theory and programming experience desired. Knowledge of X-RAYS and FORTRAN preferred. Salary $1,800 per month. Apply by May 1, 1984 to: University of California, Santa Cruz, Personnel Department, 102 Communications Building, Santa Cruz, CA 95064.

Postdoctoral in Field of Planetary Atmospheres. Start summer '84 for 12-month appointment, probably renewable. $17,500. Preferred research interests: Jupiter atmosphere aeronomy (ozone), climate modeling, radiative transfer. Send vitae to: Professor J.W. Chamberlain, Space Physics and Astronomy, Rice University, P.O. Box 1892, Houston, TX 77251.

POSTDOCTORAL RESEARCH SCIENTIST
ATMOSPHERIC RADIATIVE TRANSFER THEORY AND COMPUTATION

The Theoretical Division of the Los Alamos National Laboratory has available a postdoctoral research appointment for work on modeling the atmospheric radiation balance for climatology applications. Individual should be interested in and qualified to develop new computational solution techniques for the radiative transfer equation.

- **Scope of work:** Knowledge of computational methods to analyze solar radiative transfer through the atmosphere and experience in FORTRAN programming and handling of large data libraries is desirable.
- The position offers opportunities for use of our large computer facilities, for exciting interdisiplinary research, and for collaboration with other research teams.

Los Alamos National Laboratory is operated by the University of California for the Department of Energy. Our location in the mountains of northern New Mexico offers a clean environment and ample recreational activities. Postdoctoral appointments are for one year and may be renewable for a second year. Candidates no more than three years past their Ph.D. are invited to apply.

To apply, send a resume and a brief letter describing your research interests to:

Dr. S. Gersti, DIV–84-AY
Theoretical Division
MS B210
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

University of California
LOS ALAMOS
An Affirmative Action/Equal Opportunity Employer

Micrometeorologist. Department of Agronomy, Purdue University, tenure track appointment as assistant or associate professor depending on qualifications and experience. Ph.D. required in micrometeorology, biometeorology or agrometeorology. The successful applicant will assume teaching and research duties in the atmospheric sciences sponsored jointly by the Department of Agronomy and Geosciences. The teaching responsibilities include an undergraduate course in meteorology, an undergraduate course in boundary layer meteorology each academic year plus a graduate level micrometeorology course in alternate years. The research effort should be in the general area of boundary layer processes. Application Deadline: May 1, 1984 or until position is filled. Date Available: June 1, 1984.

Applications should be forwarded to M. W. Phillips, Head, Department of Agronomy, Purdue University, West Lafayette, IN 47907, phone (317) 494-4774, or Professor J. E. Newman, Chairperson of Screening Committee same address, phone (317) 494-8100.

An Equal Opportunity Affirmative Action Employer.

Postdoctoral Position in Upper Atmospheric Physics. A postdoctoral position is available in the Space Physics Research Laboratory at the University of Michigan for a qualified candidate with a Ph.D. degree and experience in Upper Atmosphere Physics. The position involves the analysis of data obtained from two instruments flown on the NASA Dynamics Explorer-2 satellite. The extensive satellite data base provides detailed information of the Dynamics, Thermodynamics and Compositional Structure of the Neutral Upper Atmosphere. The appointment will be for one year (renewable) and is to start in October, 1984. The applicant should identify and describe areas of his or her expertise that can support theoretical investigations in Upper Atmosphere Physics. A resume and the names of three persons knowledgable of the applicant's experience should be forwarded to:

Dr. T.L. Killeen
Space Physics Research Lab.
Department of Atmospheric and Oceanic Sciences
The University of Michigan
2455 Hayward
Ann Arbor, MI 48109-2143

The University of Michigan is a non-discriminatory/affirmative action employer.

Universite du Quebec a Rimouski, Faculty Position, Full-time Professor of Geological Oceanography. *FUNCTIONS:* The successful candidate will be required to teach courses at the undergraduate level and in the master and Ph.D. oceanography programs. He will be expected to collaborate with existing research programs in the fields of benthic-boundary layer biogeochemistry and coastal sediment dynamics, and/or to elaborate and develop a new research field in geological oceanography and to develop new courses in own area of specialization. *REQUIREMENTS:* The successful candidate must possess a doctorate in geological oceanography (or equivalent) with specialization on recent marine sediments. All applications will be treated confidentially. Interested persons should send their curriculum vitae before *May 15, 1984* to: Jean Lebel, Directeur, Département d'Océanographie, UNIVERSITE DU QUEBEC A RIMOUSKI, 300, ave des Ursulines, Rimouski, P.Q. G5L 3A1.

Scientist/Senior Physical Analyst for Supporting Remote Sensing Experiments & Data Analysis.

Areas include: 1) development and optimization of tracking algorithms for satellite altimeters for ocean topography & terrain mapping, 2) analysis of atmospheric ozone estimations based on radiation transfer measurements from rocket & balloon launched sensors, 3) study *laser beam* interaction with ocean surface with application to oceanographic lidar experiments. Minimum requirements: published or prepared reports in one of three areas above, familiar with Monte Carlo methods of radiation transfer studies. Three years experience, PhD Physics or Electrical Engineering. 40 hours/week. 8-4:30. $770/week. Location: Wallops Island, VA. To apply send resume with copy of ad attached to Joyce Spruill, Virginia Employment Commission, 5145 East Virginia Beach Blvd., Norfolk, VA 23502. J.O. #1071078.

University of Arizona/Tandem Accelerator Mass Spectrometry. A position is available for a junior or experienced postdoctoral scientist at the National Science Foundation Facility for Radioisotope Analysis at the University of Arizona. The facility is used primarily to detect and analyze the presence of ^{14}C, ^{10}Be and other rare isotopes in samples of scientific interest, and for research on applications of accelerator mass spectrometry. Half of the time on the Facility is reserved for collaboration with off-site users, and the other half is used for in-house research programs. The person hired for this position will be responsible for physics aspects of the tandem accelerator and associated equipment, and will have the opportunity to develop research programs utilizing the Facility. Salary will be commensurate with experience. Available now. Contact Professor D. J. Donahue, Department of Physics, University of Arizona, Tucson, Arizona 85721 (602-621-2480).

The University of Arizona is an equal opportunity affirmative action employer.

Marine Research Associate III. Postdoctoral position: a two-year postdoctoral research associate position available immediately, for studies of the western Sargasso Sea from the subtropical convergence to the Gulf Stream. The research involves integration of current meter, hydrographic and XBT data with satellite thermal IR digital data. The primary scientific emphasis will be on mesoscale near surface dynamics and on air/sea interaction in the region. Facilities include a VAX 11/750 with a sophisticated image processing system dedicated to project a large historical digital data base and extensive data acquisition program of the Western North Atlantic. Send resume and three professional references by May 1, 1984 to: David L. Evans, Marine Research Associate III position, THE UNIVERSITY OF RHODE ISLAND, P.O. Box 457, Kingston, Rhode Island 02881-0357.

An AA/EOE m/f

Southwest Research Institute/Ion Mass Spectrometry. A senior staff position is available in the Southwest Research Institute's Department of Space Sciences for a Ph.D. level experimental physicist to work in space-borne ion mass spectrometry. The successful applicant will have the opportunity to develop ion mass spectrometers for spacecraft missions in the earth's magnetosphere as well as to comets and planetary magnetospheres. The position requires significant experience in magnetic ion mass spectrometry and in microchannel-plate imaging detector systems. Contact J. L. Burch, Southwest Research Institute, P.O. Drawer 28510, San Antonio, TX 78284, telephone 512-684-5111, extension 2526, or Bill Crandell, Personnel Department, extension 2072.

POSITIONS WANTED

Oceanographer, Ph.D. "Extensive experience in the measurement, analysis and interpretation of multidisciplinary oceanographic data. Chief scientist and principal investigator for many research projects. Marine environmental impact assessment, marine pollution, underwater acoustics. Publications. Interested in research and/or managerial position. P.O. Box 55373, Seattle, WA 98155.

AGU

William L. Chameides: New JGR Editor

Maintaining high quality of papers while decreasing review time is among the goals set by *Journal of Geophysical Research* editor William L. Chameides, associate professor at the Georgia Institute of Technology's School of Geophysical Sciences. On January 1 Chameides officially began his 4-year term as editor of the section of the journal that emphasizes atmospheric chemistry and physics. He succeeds Ralph J. Cicerone.

Chameides says he will follow in Cicerone's tradition by maintaining the high quality of the journal and the broad scope of papers published relating to atmospheric science. He hopes to broaden further the journal's scope by incorporating more multidisciplinary papers. Increasingly, atmospheric scientists are becoming concerned with problems relating to biogeochemical cycles, global pollution and climate, global habitability, cloud physics, and acid rain, Chameides explained. The solutions to these problems, he added, will require the collaboration of scientists with capabilities in a wide variety of disciplines. It is Chameides' hope that JGR will serve as a forum for the exchange of ideas and new findings among this broad and multidisciplinary community of scientists.

As another way to broaden the journal, the editor also plans to include papers on new instrumentation and sampling techniques for gathering atmospheric data. In the past, said Chameides, papers dealing with new techniques were usually published in journals specializing in instrumentation, journals not widely read by atmospheric scientists. By publishing developments in instrumentation, these new techniques can be rapidly appraised by atmospheric research scientists, the people who are most interested in their development.

To foster communication among scientists in different disciplines, Chameides suggested that following the table of contents in each issue of the atmospheric sciences section of JGR should be a list of relevant papers appearing in the other sections of JGR. In this way, he explained, atmospheric scientists would be alerted to papers of interest in the other sections. This is particularly important for papers touching on the interfaces between ocean and atmospheric sciences.

One administrative change that Chameides has instituted aims to decrease the review time to 5 weeks. Before sending out a submitted manuscript, candidate reviewers will be telephoned to ascertain whether they have the time and inclination to review the paper within a reasonable period. If the potential reviewer can do the review, the manuscript is sent out; if not, another reviewer is queried. All editors follow this practice.

As a first for JGR, the new editor plans to publish as a special issue the proceedings of the forthcoming Seventh International Conference on Atmospheric Electricity.

Chameides' current research interests include theoretical studies of the composition of planetary atmospheres (including tropospheric gas-phase and aqueous-phase chemistry), biogeochemistry, and atmospheric electricity. He was one of three recipients of the 1983 AGU James B. Macelwane Award in recognition for his contributions to the geophysical sciences (*Eos*, August 2, 1983, p. 489). Chameides received a B.A. degree in physics in 1970 from the State University of New York at Binghamton. He received an M.Ph. degree in 1973 and a Ph.D. in 1974 from the Yale University department of geology and geophysics. He has been an associate professor at the Georgia Institute of Technology since 1980. Before that, he was an assistant professor for 4 years in the physics and astronomy department at the University of Florida. While there, he was awarded the Sigma Xi Faculty Research Award.

When not busy with his research or with his editorial duties, Chameides can most often be found at home with his two sons, Daniel and Michael. He also enjoys reading fiction, playing basketball, and going to the movies.

Questions about the journal, comments, suggestions, and papers should be sent to William L. Chameides, Editor, JGR, School of Geophysical Sciences, Georgia Institute of Technology, Atlanta, GA 30332. Chameides' term as editor ends December 31, 1987.—*BTR*

AGU Membership Applications

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary affiliation.

Sugyanto Amirwandi (H), Walter Bawiec (V), Nathan E. Bixler (H), Susan Burke (O), Chung Chan (SM), Richard B. Codell (H), Irene P. DelPalma (O), Reinhard E. Flick (O), Kristen E. Franz (H), Chien-Cheng Fu (O), Hiroyuki Fukuyama (V).

Pieter M. Grootes (V), Eiji Ito (S), Steve Jarpe (S), Boenjamin Kartawiria (H), Terry E. C. Keith (V), Douglas R. MacAyeal (O), Masamichi Miyamoto (P), Cynthia A. Moncreiff (O), Jahan Noorishad (H), Coert Olmsted (SM).

Robert G. Rader (O), K. Ramachandran (H), Dede Rasyid (H), James C. Ratte (V), M. M. Sarin (V), Dieter Seidl (S), Atula Senaratne (H), Ulrich Siegenthaler (O), Ellen J. Steiner (A), Thorkild Thomsen (H), Oesten A. Tihem (H), Barbara Valentino (T), Francisco P. J. Valero (A), Aldo V. Vecchia (H), Biquan Wang (S), Ken Watson (H), Catherine Willis (H), Kenneth Winnick (O), Bao-Zhen Zhu (A).

Student Status

Craig Bunting (S), Christian P. de Moustier (O), Martin Dougherty (T), Kevin Robert Durkee (A), Shelley Gron (V), Vicki Harder (T), Jene Hendrickson (H), Ken Herkenhoff (P), Claude M. Laird (SA), Shawn Larsen (G), Xiang-Dong Li (S), Ruth L. Lindsley (P), Jeffrey E. Lucius (GP).

Mark L. Morrissey (A), J. Daniel Moses (SC), R. Ian Perry (O), Maureen E. Raymd (O), Steven T. Recca (V), Bruce A. Savage (V), David R. Scott (T), Ludwik Sliwa (G), Chris Sweazy (P), Robert J. Taylor (O), Mark Walker (H).

Meetings

Announcements

Groundwater Geochemistry

June 22–26, 1984 Practical Applications of Groundwater Geochemistry, Banff, Alberta, Canada, Sponsors, the Alberta Research Council and the National Water Well Association. (David Nielsen, NWWA, 500 W. Wilson Bridge Road, Worthington, OH 43085.)

Registration deadline is May 15, 1984.

The conference will feature formal lectures on "Fundamental Aspects of Groundwater Geochemistry" as well as a series of short talks on "Groundwater Geochemical Methods Applied to Specific Field Problems Presented by You." There will also be a number of concurrent panel discussions on "Application of Groundwater Geochemistry to Solve Problems of Practical Interest to Participants." The conference will be limited to 300 participants and will take place at the Banff Springs Hotel, near Calgary.

American Astronomical Society

October 9–12, 1984 16th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society, Kailua-Kona, Hawaii. Sponsors, the Hawaii Institute of Geophysics and the Institute for Astronomy of the University of Hawaii. (Tom McCord, Planetary Geosciences Division, Hawaii Institute of Geophysics, University of Hawaii, 2525 Correa Road, Honolulu, HI 96822.)

Abstract deadline is August 10, 1984.

Contributed reports from all areas of planetary science are welcome. Abstracts in the standard AAS format should be postmarked by August 1 and should be sent to the program chairman, Tom McCord, at the above address.

Plan for AGU Fall Meeting

Plan for San Francisco now. The AGU Fall Meeting will be December 3–7, 1984.

The 1984 Fall Meeting will also incorporate the winter meeting of the American Society of Limnology and Oceanography.

The meeting will take place in the San Francisco Civic Auditorium. This building will house under one roof all of the simultaneous sessions needed.

To avoid as many conflicts as possible, a large number of poster presentations will be scheduled. Program chairmen will be planning special poster sessions, and authors will be encouraged to present poster papers. The very large arena in the Civic Auditorium will make an excellent site for the poster papers. This arena will also provide space for a substantially larger exhibit than has ever been seen at a Fall Meeting, and the refreshments and registration will also be in this area.

Housing will be primarily at the Cathedral Hill Hotel, the Holiday Inn-Golden Gateway, the San Franciscan Hotel, and the Holiday Inn-Civic Center. The latter two are near the Civic Auditorium. Shuttle buses are planned for those who cannot or will not walk from the Holiday Inn-Golden Gateway and Cathedral Hill.

The formal Call for Papers will be published early in the summer. The abstract deadline will be in early September. Housing and registration information will be published in early fall.

Meeting Report

Pacific Northwest AGU Meeting

The 30th AGU Pacific Northwest Regional Meeting was held September 29 to October 1, 1983, on the campus of Western Washington University, Bellingham, Wash. Approximately 125 attended the meeting, and 36 papers were presented. The meeting included two fields trips, five special symposia, and a banquet where keynote speaker Don Swanson presented "Dome building on Mt. St. Helens."

The meeting highlights included a symposium on Tertiary sedimentary basins of Washington and Oregon which revealed the importance of sedimentological studies for deciphering the timing and nature of accretionary processes in tectonically active areas. Geological and geophysical studies on the recent tectonics of the Juan de Fuca plate and nearby continent were presented by workers from the United States and Canada as well as ongoing studies for the evolution and character of the crystalline North Cascades of Washington and British Columbia.

Special acknowledgments must go to the Conference Center at Western Washington University for handling the logistics of the meeting.

This meeting report was prepared by David C. Engebretson *and* Myrl E. Beck, Jr., *Department of Geology, Western Washington University, Bellingham, WA 98225.*

Abstracts

Mineralogic Terrains and Tectonic Timing -- Quimper Peninsula, Northeast Olympic Peninsula, Washington

JOHN M. ARMENTROUT, Mobil Exploration and Producing Services Inc., P. O. Box 900, Dallas, Texas 75221

Eocene stratigraphy of the Quimper Peninsula area consists of two adjacent mineralogically distinct terrains separated by a fault zone and unconformably overlain by a third mineralogic terrain.

Lower through Middle Eocene (Penutian to early Narizian Foraminiferal Stages) arkosic sandstone of Scow Bay occurs east of the fault zone and has paleocurrent features suggesting a sediment source area to the south or southeast. Lower to Middle Eocene (Penutian to Ulatisian Foraminiferal Stages) Crescent Formation tholeiitic basalts and locally derived basaltic sandstone of Maynard occur west of the fault zone. Unconformably overlying the above units is Upper Eocene (Refugian Foraminiferal Stage) Quimper Sandstone, a marine lithic sandstone with abundant plagioclase and basalt grains suggesting local erosion and mixing of both underlying Lower to Middle Eocene mineralogic terrains. These relationships suggest that the western basaltic terrain was juxtaposed against the eastern arkosic terrain and both terrains uplifted and actively eroded by early Late Eocene (Refugian Foraminiferal Stage) time approximately 38 Ma.

The fault zone, mapped west of Anderson Lake, may be a segment of the Discovery Bay fault system, and possibly represents a tectonic suture between oceanic tholeiitic basalt terrain and cratonic arkosic terrain.

Geochemistry of the Crystalline Core of the North Cascades Range

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The crystalline core includes the Marblemount Meta-Quartz-Diorite (MMQD), the Cascade River Schists (CRS), the Skagit Gneiss Complex (SGC) and the Eldorado Orthogneiss, plus dikes, sills and plutons which cut the main stage metamorphic rocks of the CRS and SGC. The MMQD consists chiefly of metaluminous tonalite cut by minor peraluminous, muscovite-bearing dikes that share the foliation of the host rock. The CRS is composed mainly of metasedimentary and minor metavolcanics that generally reflect a calc-alkaline and tholeiitic protolith. Rb/Sr analyses of the SGC are similar supracrustal "remnant" rocks in the SGC minimum age scattered but suggest an early Paleozoic minimum age for the source material. Supracrustal rocks in the SGC are quite similar to CRS in major and trace element composition, supporting the interpretation that the CRS is a lower grade stratigraphic equivalent of the SGC. Metamorphic leucosomes of migmatites in the SGC are peraluminous trondhjemites that are more sodic and silicic than metaluminous orthogneisses, intruded prior to, or during, the main stage of metamorphism. The Eldorado Orthogneiss is also well foliated and metaluminous, but is of granodioritic to tonalitic composition. Granitic dikes which cut the main-stage SGC migmatites have the same b-lineation as their wallrocks and yield a Rb/Sr WR age of 45 ± 0.9 Ma with a low initial Sr ratio of .7040. The trondhjemitic Marble Creek orthogneiss, associated with the CRS, appears to be of similar age (or slightly younger), but is more sodic and has a higher 87/86 Sr ratio.

The Tectonic Setting of the Montesano Formation (Late Miocene), Southwest Washington

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The Montesano Fm., a marine shelf unit in southwest Washington, is unique because of its lack of correlative marine strata in the state and because it shows characteristics of two tectonic terranes. The formation exhibits the dominance of a marginal basin adjacent to an active orogen, it., the Olympic Mountains, as well as a fore-arc basin to the west of the Cascade arc.

Petrologic results show a mixed source. Sedimentary clasts of the Olympic core and basaltic clasts of the Crescent Fm. show varying degrees of low-grade metamorphism, petrographic textures, and weathering, indicating a deeply incised source of relatively large area to the north. Felsic clasts and glass shards suggest an arc-derived source from the east. Work in progress will define distinctions with the underlying Astoria (?) Fm., a unit that has similarities with the Montesano in certain sections, but is generally quite different in sedimentary texture. These distinctions could help to identify Montesano and Astoria(?) strata further to the south, where outcrop distinctions are less clear.

Clasts of the Astoria(?) Fm. indicate that uplift of an Olympic source area had occured earlier in the middle Miocene, although on a much smaller scale than during the late middle Miocene. The latter relationship is evidenced by a regional unconformity at the contact between the Montesano and Astoria(?) Formations.

Olympic orogenesis may therefore have proceeded as a series of pulses in the middle and late Miocene. Long periods of quiescence are indicated by the dominantly sandy mudstone and occasional coarse-grained influx of the Astoria(?) Fm., culminating in erosion and later deposition of coarser-grained Montesano sediments. Further uplift occured in the Pliocene.

Structure of the Grays Harbor Basin as Evidence for Post 12 M.Y.B.P. Tectonic Activity in S.W. Washington

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The Grays Harbor Basin occupies a depression structurally controlled by middle to late Eocene basalts of the Crescent Fm. and equivalent rocks in the Black Hills, Doty Hills and the Willapa Hills. This Eocene basement forms a broad syncline with a general plunge to the west.

Later structures record distinctive styles and ages of folding and faulting within the basin. Late middle Miocene folding created a smaller Grays Harbor Basin. Major northeast-trending faults with a strong right-lateral strike-slip component are found in strata older than the Montesano Fm., a late Miocene sedimentary unit. Numerous smaller associated northwest-trending normal faults are found near the larger faults.

Structures younger than the Montesano Fm. (<12-9 m.y.b.p.) are less common, but record significant movement. Large northwest-trending faults with left-lateral strike-slip are common in the northern basin. These faults may represent strike-slip movement on older normal faults developed during the middle Miocene and earlier, as suggested by W.W. Rau. Smaller northeast- to northwest-trending right-lateral strike-slip faults show only minor displacement.

Post Montesano folding is observed in the north-trending Satsop Syncline, Melbourne Anticline and the Wynoochee Anticline, which apparently are reactivations of older uplift. Broader east-trending folds such as the Still Creek Syncline reflect the older structural control of the basin throughout the Tertiary.

Faulting that postdates Montesano deposition compliments paleomagnetic evidence for 15 degrees of clockwise rotation found in 12 m.y.b.p. basalts in the Grays Harbor Basin of southwestern Washington.

Is Pacific NW subduction active, decaying or incipient? The 2-m geoid

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Evidence of subduction is abundant in the Pacific NW, but features such as a Meinesz gravity trough & deep seismicity are missing. We have used the 2-meter geoid and considerations of mantle circulation as a guide to the status of the subduction in the Pacific NW. The 2-m geoid displays a distinctive "signature" in regions of the western Americas where subduction is known to be active. In regions such as California where subduction appears to have become extinct, its geoidal expression likewise has dissipated or is in the process of dissipation.

The tectonic development of the Pacific NW appears to be a continuation of that to the south. At the latitude of the Californias, as N America has reached the crest of the East Pacific Rise subduction has died out. Crestal extension either has died out or has "jumped" in the fashion described by Wood (1983) to a location such as the Gulf of California within the continental margin. If this diagnosis is correct, subduction has been active beneath Oregon & Washington, but is now decaying. The Cascades volcanism is in this case the product of convergence due principally to the westward motion of N America and the heating of material previously subducted. The structure of the northern boundary of the Basin & Range province, dextral shears or transforms, suggests that as N America approaches the Juan de Fuca segment of the East Pacific Rise, the BR province will extend northwards into Washington. The triple junctions at Cape Mendocino & Cabo Corrientes will continue to move further apart, tracking the extinction of subduction.

Crustal Structure Beneath the Sapphire Tectonic Block and the Idaho Batholith of Southwestern Montana

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We used portable seismographs to record Pg (crust) and Pn (mantle) waves at 22 sites from blasts in Anaconda Minerals Company's open pit mine in Butte, Montana. The recording sites are regularly distributed along a 280 km line that extends northwest from Butte to near Wallace, Idaho. We recorded blasts on several days and fixed origin times by using an array of permanent seismographs around Butte that are operated by the Montana Bureau of Mines and Geology. No blasts are available near Wallace that allow reversal of this seismic refraction profile.

We recorded Pg arrivals at all of the sites and Pn first arrivals at the most distant four sites. The Pg wave travels at a velocity of 6.1 km/sec and the Pn wave travels at an apparent velocity of 7.6 km/sec. For an over simplified, two horizontal-layers model, these velocities and a Pn intercept time of 6.9 sec suggest a depth to the Moho of 35 km. This result is congruent with the thickness of the crust near Butte, but it is most likely too thin for the area near the Idaho batholith. The Pn velocity is also too low for the area we investigated. If we use a more reasonable velocity of 8.0 km/sec for Pn then our data suggest that the Moho dips about 2.5° to the northwest along our refraction line. Thus, the thickness of the crust increases from 35 km near Butte to about 50 km near Wallace.

This crustal thickness is somewhat greater than predicted for the area and shows that Tertiary extension has not been as effective in thinning the crust in this part of Montana as it has in the area immediately southwest of Butte.

Implications of Heat Driven Extension for some Cenozoic Structures in Oregon

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Long term strain produced by a right-lateral Brothers Fault Zone (BFZ) can account for the pattern of folds, normal faults, and tear faults (e.g. Indian Cr.) in east-central Oregon. Fold axes ranging in age from 40? -0 Ma are coincident, implying that the BFZ is an old structure which is continually reburied and displays only Riedel shears in young surface rocks. South of the BFZ heat driven extension and consequent listric normal faulting, active for a minimum of 25 my, would best explain the increasing dips with age seen in Winter, Abert, and Steens scarps. Ignimbrites and domes throughout central and southern Oregon with 36-15 my ages testify to strong mid-Cenozoic crustal heating. The BFZ appears to end westward at Newberry volcano. More rapid extension south of the BFZ would produce both extensional Fe-Ti rich arc lavas from, and a graben along, the north-central portion of the Cascade arc. Fe-Ti rich Scorpion Mtn. (25-18 Ma) and Deschutes Fm. (8-3 Ma) lavas appear to mark two episodes of such extension – the first due to profound heating culminating some 20-25 Ma followed by slow cooling, and the second due to reheating beginning some 10 Ma (the age progression of domes 10-4 Ma). We suggest that the Sardine Fm. fills a graben which has been rotated CW away from the site of its formation. CW rotation of western Oregon rocks is a consequence of extension increasing southward from Montana to Nevada. A monotonic increase in such extension would lead to constant rotation of western Oregon and no rotation of the Klamath Mtns. The step-like increase in extension across the BFZ appears to require decreasing rotation southward in the Western Cascade and Coast Ranges.

Co-operative systematic surveys over the northern Juan de Fuca Ridge system, 1983: a progress report.

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Four major marine surveys were carried out during 1983. The first was a joint NOS/PGC and Univ. of Washington SEABEAM survey from OSS SURVEYOR which completed detailed bathymetric coverage of the ridge up to its intersection with the Sovanco FZ. In July, a five-week multi-parameter (gravity, magnetic and bathymetric) survey at 10 km spacing from CSS PARIZEAU continued coverage out to 200 n. miles southwest of Vancouver Island. This covered the northern part of Juan de Fuca Ridge, the Sovanco FZ and Explorer Ridge and was conducted by PGC in co-operation with the Canadian Hydrographic Service (CHS).

During August and September two cruises concentrated on the northern components of the spreading system – the Tuzo Wilson Knolls, Dellwood Knolls and Explorer Ridge. These were a continuation of SEABEAM coverage by NOS from OSS SURVEYOR and a joint PGC/CHS and Univ. of Hawaii cruise on RV KANA KEOKI using SEAMARC II.

The combined data from these cruises provide a range of information from the regional to the detailed which will form the basis of a comprehensive atlas of the Juan de Fuca Ridge system. It is planned that this will form the foundation for programs of detailed site and problem investigations and deep dives which are planned for 1984 and 1985.

An Analytical Method for the Determination of Gravity Terrain Corrections in Mountainous Terrain

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Improved and consistent values of terrain corrections can be obtained if the elevation range between the bottom of the river valleys and the tops of mountain peaks is taken into account as if it were a layer of material of variable density, gradually decreasing with height. The method is comparatively fast, quite accurate, and can be programmed for a small pocket calculator, so that terrain corrections can be determined immediately in the field.

Complete Bouguer Gravity Map of the Cascade Mountains, Washington

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The above map has been completed and published as a joint of the State of Washington, Department of Natural Resources and the U. S. Department of Energy. It is divided into two sheets along the 47°N parallel, at a scale of 1:250,000, with a brown half-tone background topography. The contour interval is 5 mgal, surface reduction density 2.67 gcm^{-3}.

For technical reasons, terrain corrections north and south of the 47th parallel had to be calculated differently; as a consequence, there is a tare ranging from zero up to about 5 mgal between the two sheets. Gravity values at major volcanic peaks should probably be recalculated with a surface density of about 2.3 gcm^{-3}.

Analysis and interpretation of the various anomalies are in progress.

A Geomagnetic Depth-Sounding Profile Across Queen Charlotte Sound, British Columbia, Canada

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During July and August 1983, ocean bottom magnetometers were deployed at 3 sites for a profile extending across the Queen Charlotte transform fault near the southern extremity of Queen Charlotte Islands. Water depths for these locations are 3010 m (site 1), 2040 m (site 2), 177 m (site 3). A magnetometer was also installed at Tasu on land about 385 km east of the continental shelf site 3. Both the in-phase and quadrature-phase parts of the geomagnetic vertical to horizontal response at site 2 have unexpectedly large amplitudes (up to 1.8) between 10 and 100 minute periods. The quadrature induction arrows at site 2 point southward (unexpected), but the in-phase induction arrows rotate with decreasing period from a southwesterly (expected) to a southeasterly (unexpected) direction, paralleling at short periods the strike of the shelf-slope break. For the remaining locations the induction arrows are directed southwesterly, consistent with the usual [illegible] concentrations paralleling the strike of the shelf-slope break. These responses and arrows for site 2 are certainly the result of electric currents concentrated in some unknown 3 dimensional electric conductivity distribution beneath the seawater. The distribution could be the result of the site proximity to oblique subduction beneath Queen Charlotte Islands, to the triple junction for the Pacific, America and Explorer Plates, and large accumulations of sedimentary materials beneath Queen Charlotte Sound.

Relative Motions between Oceanic Plates of the Pacific Basin

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Relative motion poles for the displacement histories between the Pacific Plate and once adjacent oceanic plates (Farallon, Kula, Izanagi I, Izanagi II and Phoenix) were derived for the late Mesozoic and Cenozoic Eras. The following are the main conclusions drawn from our analysis. (1) For time intervals of the order of 10^7 years, termed stages, the relative motion pole for a plate pair remained nearly fixed. However, the rate of plate motion commonly changed within a stage, indicating that changes in plate speed occurred more frequently than changes in direction. (2) Changes in the relative motions of all of the plates analyzed occurred at about chron M11 (135 Ma), chron 34 (85 Ma) and chron 25 (56 Ma). (3) During the Early Cretaceous there were three triple junctions relating five oceanic plates in the Pacific basin rather than the two triple junctions relating four plates recognized by previous workers. (4) Fracture zones and magnetic anomalies that record Pacific-Farallon spreading from chron 34 (85 Ma) to chron 25 (56 Ma) from the northern, central and southern Pacific Plate were analyzed separately and collectively and show that a single Pacific-Farallon relative motion pole and a single rate are consistent with all of the data. (5) Spreading rates along the Pacific-Kula ridge uniformly decreased between chrons 32b and 25 (72 to 56 Ma) probably in response to the interaction of a progressively younger and hence more buoyant Kula Plate in a subduction zone to the north. (6) Soon after chron 25 (56 Ma), a major reorganization in the Pacific-Farallon and Pacific-Kula spreading systems occurred, possibly accompanied by an abrupt increase in Pacific-Kula spreading.

Initiation of the North Fork Toutle River lahar by liquefaction of debris avalanche deposits during the May 18, 1980 Mt. St. Helens Eruption

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Data I have gathered indicates that the North Fork Lahar (NFL) was generated when saturated deposits of a part of the debris avalanche liquefied during a long harmonic tremor event that began at approximately 1140, 3 hours after the eruption began. Eye-witness observations on May 18 and my field observations confirm that the source of the NFL was a small section of debris avalanche deposits (emplaced earlier on May 18) near Elk Rock. The strong correlation between the timing and magnitudes of seismicity and lahar discharge strongly suggests that liquefaction generated the lahar; mud was observed ponded at the source of the NFL shortly after seismicity began and the peak of lahar discharge on the avalanche coincides with peak seismic energy. Field evidence and a physical model of ice melting support the conclusion that only in this small part of the avalanche were ice blocks small enough to produce a large volume of intergranular meltwater and saturate the avalanche deposits by the time seismic shaking began. An empirical engineering model of liquefaction is consistent with the conclusion that the saturated debris could have liquefied.

The NFL was approximately an order of magnitude more voluminous than any of the other lahars initiated during the May 18 eruption, and was commensurately more damaging because of its unusually long duration and sustained peak discharge. Another unique characteristic of the NFL was that it started moving down channel at approximately 1310, 4.5 hours after both the eruption began and after the other lahars were initiated. My results indicate that the delayed initiation, long duration, and sustained peak discharge of the NFL can be directly related to correlative characteristics of the harmonic tremor event. The harmonic tremor event, therefore, controlled the ability of the NFL to cause damage.

Evidence for the late Eocene Accretion of Peripheral Rocks of the Olympic Peninsula, Washington

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Buchan (low P) metamorphism of the Leech River Complex (LRC) of southern Vancouver Island ended ~40 mya. Metamorphism of this type and age is unknown elsewhere in western Washington and Vancouver Island and suggests that the LRC was allochthonous and emplaced after 40 my. The Eocene Crescent and Metchosin basalts (C-M), which are in contact to the south of the LRC along the Leech River fault (LRF), could not have been emplaced until after the LRC. Geomagnetic and field data strongly suggest that the LRF is strike-slip, and we propose that Eocene peripheral rocks of the Olympics (including C-M) moved eastward during their accretion to western Washington, accommodated by at least 65 km of left-lateral motion on the LRF. Movement must have concluded before deposition of the late Oligocene Carmanah Fm., which is not displaced by the LRF.

This hypothesis predicts large-scale, east-west shortening south of the LRF after 40 my. The following evidence indicates that correlative large-magnitude shortening occurred on proposed thrust faults of the Discovery Bay fault system (DBF) on the eastern Olympic Peninsula: (1) A profound sedimentary discontinuity mapped by Armentrout (2) a sharp geomagnetic gradient attributed to the east-dipping boundary of the Crescent Volcanics, (3) anomalous proximity of volcanic rocks of continental and oceanic affinity. Geomagnetic evidence indicates that the DBF is an extension of the LRF. Armentrout has constrained movement on the DBF to no later than ~37 my, indicating the Eocene peripheral rocks were emplaced between 40 and 37 mya.

Coeval, small displacement on reverse faults of the western Cascades and on the Devils Mountain fault may have resulted from stresses transmitted eastward during underthrusting of peripheral rocks.

Advanced Computer Graphics Applied to Geologic Problems of the Pacific Northwest

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Many of the studies carried out at Battelle, Pacific Northwest Laboratories involve spatially dependent data sets that are large and complex. To obtain the maximum amount of information from these data sets at a reasonable cost and in a reasonable time, a set of computer programs was developed to abstract, combine, and display these large data sets. To illustrate this process, several data sets are presented. Included are examples from the Cascade Mountains, the Columbia River Basin, Mt. St. Helens, the Olympic Mountains, and the Puget Lowlands. Each example illustrates how computer graphics enhances the ability of the geologist to interpret and present complex data. In particular, advantages of combining diverse data sets into one three-dimensional image are presented.

Dating of Dedolomitization by Paleomagnetism

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Dedolomitization, replacement of dolomite by a calcite pseudomorph, is a common weathering phenomenon. Weathering-related dedolomite is generally accompanied by formation of iron oxides because dolomite commonly contains a few mole percent Fe^{++}. Indeed, field evidence as well as chemical considerations suggest that under oxidizing conditions iron-bearing dolomite is much more readily dedolomitized. In some thin beds from the Jungle Limestone (Cambrian) of Frenchman Mountain in southern Nevada, iron-rich zones are completely replaced with a mixture of goethite and calcite, whereas less ferrous zones are unaltered; the contact is sharp [illegible] reported by Frank [illegible] Missouri. In other early Paleozoic limestones in the Great Basin dedolomite is also ubiquitous, associated with iron oxides. The sharpness of the contact suggests that initial alteration may occur by charge transfer of an electron from Fe^{++} to form Fe^{+++}; the Fe^{+++} disrupts the dolomite crystal. In situ by binding to hydroxyl and oxygen to form goethite; Mg^{++} escapes and calcite precipitates, probably in continuity with the unaltered dolomite.

In the Great Basin limestones, a recent time of dedolomitization fits both petrographic observations and paleomagnetic data. The NRM is dominated by a present-field component which is destroyed by thermal demagnetization to ~200°C, but which in part is also extremely resistant to AF demagnetization. These properties are typical of goethite and/or very fine-grained hematite; indeed, dedolomitization is a major source of the present-day signal due to authigenic ferric oxides.

Dating has important applications in petroleum geology, because dedolomitization is a source of diagenetic porosity. In addition, mineralization (e.g., Ur) localized at weathering surfaces can potentially be dated.

Tectonic Rotation and Basin Development during mid-Tertiary Extension in the Pacific Northwest

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The early-to-mid-Tertiary sedimentary record in the Pacific Northwest provides evidence that accretion of the Oregon Coast Range (OCR) was complete prior to tectonic rotation. The Eocene stratigraphic sequence of the OCR overlaps the northern Klamath Mountains. These strata exhibit synchronous changes in depositional style, intensity of deformation, clastic composition, and subsidence history, demonstrating that the OCR was accreted by c. 50 Ma, prior to deposition of the Tyee Fm. Because the Tyee Fm is rotated nearly as much as the volcanic basement on which it rests, rotation must have occurred after the end of this accretionary event.

The clastic composition of the Tyee Fm strongly suggests that its source area reached far beyond the Klamath Mountains and included parts of present day Idaho and northeastern Nevada. Thus the OCR basin probably lay much farther to the east during Tyee deposition, and subsequently was rotated westward to its present position. Significant rotation, therefore, did not occur during collision of the OCR, but may have resulted from a prolonged episode of extension within western North America. Extension in the Pacific Northwest initiated about 50 Ma and still continues. Mean magnitudes of rotation, as determined from the paleomagnetic record, can be accomodated by ~65% extension within the Cordillera.

Basin development occurred synchronous with extension, arc migration, and tectonic rotation. Local and regional uplift associated with extensional and thermal effects led to rapid marine sedimentation and progradation rates along the continental margin. To the east, continental sedimentation was mostly in graben or pull-apart basins. Sedimentary basin development, therefore, was intimately associated with regional extension throughout the Pacific Northwest.

Structural and Petrogenetical Indicators for an Extensional Tectonic Regime Imposed on Central High Cascade Volcanism

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Shield-building High Cascade Pleistocene-Holocene mafic lavas erupted due to crustal foundering and graben subsidence (~4.5 m.y. ago) along an earlier andesitic Cascade crest. Basalt (<53 wt.% SiO_2) and basaltic andesite (53-62 wt.% SiO_2) flow sequences inundated the depression to construct a mafic platform upon which calc-alkaline derivatives emerged. Intersecting north- and northwest-trending normal faults and vent alignments suggest an overlap of two tectonic regimes. The north-aligned faults coincide with the overall High Cascade trend of composite volcanoes whereas the north-west-aligned faults represent a protrusion of the Brothers Fault Zone into the High Cascade system.

Geochemical and petrographic data indicate a genetic separation between basalts and basaltic andesites.

Meetings (cont. on p. 330)

Meetings (cont. from p. 329)

The basalts can be derived from volatile- and LIL element-enriched upper mantle (35-45 km) sources whereas a lower crust (25-35 km) source is implied for basaltic andesites. Plagioclase phyric basaltic andesites are precursors to the silicic calc-alkaline units via fractionation of pl+opx+cpx+mgt (POAM) mineralogy. The basalts are not typical of normal calc-alkaline systems although they closely correspond to extensional mafic volcanism by their predominantly diktytaxitic texture, higher TiO_2, and a Hf-Ta-Th tectonomagmatic discrimination which places them out of the orogenic field. Structural and petrochemical relations agree with the sudden transformation from Pliocene explosive volcanic activity to Pleistocene basalt dominance suggesting a deeper source tapping during the extension of a thermally-weakened crust.

Paleolatitudes, apparent displacements and internal rotations of the Bonanza Volcanics (Early Jurassic) of Vancouver Island, B.C.

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Paleomagnetic observations from 14 sites in the Bonanza Volcanics of northern Vancouver Island have yielded a paleolatitude of 21° ± 5°. There is an ambiguity as to whether this is north or south. Assuming that it is 21°N then comparison with the Early Jurassic reference field for cratonic North America places Vancouver Island in the latitude of California with an uncertainty of about 10°. This position is not significantly different from the Karmutsen volcanics; i.e. Vancouver Island underwent little or no motion relative to North America during the Late Triassic and Early Jurassic. The motions are more complex if the south latitudinal option is assumed. The overprint we observed from the Karmutsen indicates that the northward motion of Vancouver Island required to bring it into its present position is post-mid Cretaceous. The simplest explanation of paleomagnetic data from Vancouver Island therefore is that the island was situated in the latitude of California during the Late Triassic to Early Cretaceous and moved northward to its present position in post-mid Cretaceous time. Differences of declination of up to 90° are observed at different localities in the Bonanza and provide ample evidence of very large post-Early Jurassic rotations. These may have occurred by arc-bending soon after formation, during collision with the mid-Mesozoic continental margin of North America, or during the northward movement.

Strike-slip-fault control(?) on the geometry and origin of the Eocene Chuckanut basin, northwest Washington

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The Eocene Chuckanut Formation of northwest Washington comprises as much as 6000 m of alluvial strata and is one of the thickest nonmarine sequences in North America. It is exposed in several disconnected outcrop belts that are probably remnants of a regionally extensive fluvial system. Several factors are strongly suggestive of strike-slip fault influence on the geometry and origin of the Chuckanut basin: (1) rapid sediment accumulation rates; (2) rapid facies changes; (3) an irregular basin margin characterized by dip-slip faults and intraformational unconformities; (4) deformation consistent with predicted structural patterns; (5) rapid changes between extensional and compressional tectonics; (6) interbedded and intrusive relationships with extension-generated(?) volcanic rocks.

It is proposed that the Chuckanut basin formed in an extensional zone between the right-lateral Straight Creek Fault to the east and a postulated right-lateral fault in the Puget Lowland to the west. The petrology of downbasin marine correlatives of the Chuckanut on the northeast Olympic Peninsula is inconsistent with derivation through the Chuckanut fluvial system. Missing Chuckanut marine facies may have been translated north along the inferred Puget Lowland structure.

The Puget basin to the south formed in a geometric setting similar to that of the Chuckanut basin and may have similar strike-slip-fault control.

Strain Accumulation in Vancouver Island and Washington

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The measured principal strain rates (in µstrain/a) and bearing of the axis of maximum compression across trilateration networks monitored by the U.S. Geological Survey in the Seattle, Hanford, and Olympic Park, Washington areas are as follows:

Network	Epoch	$\dot{\epsilon}_1$	$\dot{\epsilon}_2$	θ
Seattle	1972-81	-0.01±0.01	-0.12±0.02	N67°E± 7°
Hanford	1972-83	-0.02±0.01	-0.02±0.01	N 3°W±34°
Olympic	1982-83	0.23±0.23	-0.25±0.25	N47°E±13°

The measured deviatoric principal strain rates (in µrad/a) and bearing of the axis of maximum compression across triangulation networks measured by the Geodetic Survey of Canada in the Johnstone Strait and in west-central Vancouver Island are as follows:

Network	Epoch	$\dot{\epsilon}_1$	$\dot{\epsilon}_2$	θ
Johnstone Strait	1914-66	0.03±0.01	-0.03±0.01	N 5°W±10°
Gold River	1947-82	0.13±0.06	-0.13±0.05	N39°E±10°

Extension is taken as positive and uncertainties are standard deviations. The axes of maximum compression are generally close to the N50°E direction of convergence between the Juan de Fuca and North American plates. Rates of strain accumulation generally agree with those calculated from a simple dislocation model with the shallow portion of the subduction zone locked.

Magma Supply and Readjustment of the Feeding System of St. Helens during 1980

S. MALONE
G. SCANDONE* (Geophysics Prog., Univ. of Wash., Seattle, WA 98195 *Permanent Address: Osservatorio Vesuviano, 80056 Ercolano, ITALY)

A sequence of five explosive eruptions starting with the May 18 cataclysmic eruption took place over the summer and fall of 1980 at Mount St. Helens. The volume of explosive products from each of these eruptions decreased uniformly over this period, and the character of each eruption progressed from a fairly continuous eruption lasting more than eight hours on May 18 to a series of short bursts spaced 12 hours apart on October 16-18. Each eruption was followed by an aftershock-like series of earthquakes. These earthquakes were distributed at depths between 7 and 14 km surrounding an earthquake free zone of ~20 km^3. The seismic energy released during each of these eruption sequences is proportional to the corresponding volume of erupted magma.

We propose a model in which magma is supplied from a reservoir 7 to 14 km deep at a uniform rate controlled mainly by its viscosity. It rises through a narrow conduit to a shallow zone where disruption can take place and then erupts to the surface at the same or at a higher rate in explosive bursts. The deep seismic activity following each eruption is related to a readjustment and volume decrease in the deep reservoir. The transition in the character of these eruption sequences from one prolonged eruption on May 18, to isolated eruptive bursts in October can be explained by a difference in the magma supply rate to the disruption zone.

Northnorthwest Source Found for Mid Eocene Subsea Fan Deposits on Indian and Marrowstone Islands, Northwest Washington

L. A. Malin (Western Washington University, Bellingham, Washington)
(Sponsor: C. A. Suczek)

The unnamed Eocene unit well exposed on the beaches of Indian and Marrowstone Islands in Northwest Washington consists of thick to very thick bedded sandstone with minor shale interbeds. There are also at least two 20 to 30 meter thick shale beds. Sandstone beds are commonly ungraded and massive. Dish structures, poorly developed parallel lamination, load casts and shale rip-up clasts are locally abundant. Amalgamation of several thick sandstone beds into very thick (3-5 m) beds is common although often difficult to recognize due to the massive nature of the beds. The shale beds are massive or laminated with rare climbing ripple cross-stratification. Several penecontemporaneous slumps are present. The section along the east coast of Indian Island was measured and described in detail revealing at least eleven thinning and fining upward sequences. Uncommon flute casts indicate a source to the northnorthwest. The unit was deposited as channel fill sequences on the mid-fan region of a subsea fan. The two thick shale beds were deposited on inactive regions of the fan between active channels.

Deposition from various types of sediment gravity flows is indicated including fine grained debris flows, grain flows, liquefied flows and rare turbidity currents.

Punctuated Volcanism in Oregon's Coast Range

KRISTINE N. MCELWEE and R.A. DUNCAN (School of Oceanography, Oregon State Univ., Corvallis, OR 97331)

New K-Ar age determinations performed on upper Eocene basaltic rocks of the Oregon and Washington Coast Range help to constrain tectonic models of their origin. Three episodes of late Eocene to Oligocene volcanism have been recognized: 46 to 41 my, 37 to 33 my, and 30 to 27 my. The earliest activity spanned a period from 46 to 41 my and produced the upper Tillamook Volcanics of northwestern Oregon and the Goble Volcanics of southwestern Washington. Volcanic rocks of this age in the Coast Range are restricted to occurrences near the Columbia River, in contrast to the more extensive outcrop area of the Paleocene to Eocene Coast Range basaltic rocks and of the coeval arc volcanic rocks erupted in the Western Cascades. Microplate rotations inferred from paleomagnetic data differ by 30° across the Columbia River and suggest that this region has acted as a hinge between the northern and southern ends of the Coast Range. The restricted outcrop of 46 to 41 my volcanics may be the result of hotspot influence (which last produced basaltic volcanism in the Gray's River area at 48 mya), crustal weakness in the area of the Columbia River, or both. Volcanic activity in this area recommenced at 37 my and continued to 33 my. Between 34 and 33 my flows of the Yachats Basalt and the Cascade Head Volcanics were also erupted in the central Oregon Coast Range. Dioritic, syenitic and camptonitic magmas were intruded in these two areas from 30 to 27 mya. No intrusive rocks of this age have been found in northern Oregon or Washington.

Moderately deep-water siltstones of the Nestucca Formation underlie and, in places, overlie the largely subaerially erupted Yachats Basalt, indicating rapid, localized vertical movement. This may have been the result of thermal expansion of the lithosphere in response to the injection of a large, hot body of magma, a change in plate convergence rate or direction, or doming as the margin of North America overrode a hotspot.

Mid Tertiary History of the Oregon Western Cascades

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Fossiliferous Middle Tertiary marine rocks of the Oregon Western Cascades lend themselves particularly well to interpretation of the local and regional geologic history. Tectonic instability in the Eocene-Miocene interval here is reflected by abrupt sea level changes, rapid influx of volcanigenic material, increased erosion and high sedimentation rates.

By utilizing paleomagnetic data, other workers have only recently generated a new model for Pacific Northwest tectonic history. The latter model appeals to an allochthonous origin for what is now the Oregon Coast Range and Willamette Valley.

In the course of our work on the geology of the Western Cascades we have identified several apparent irregularities in the fossil faunal distributions, sedimentology and physiography. Most of these anomalies may be explained if we adopt the new tectonic model as a common denominator to the regional geology.

Tectonic Evolution of the Southern Margin of the Skagit Crystalline Core of The North Cascades

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(Sponsor: P. Misch)

Obduction, regional metamorphism, and plutonism occurred at the southern margin of the Skagit crystalline core during a brief interval in the mid-Cretaceous. The Windy Pass thrust (WPT) carried the Late Jurassic Ingalls ophiolite northward onto the pelitic Chiwaukum Schist of the Skagit core. Above the WPT, the Ingalls is imbricated with metasediments and orthogneisses. Imbrication coincided with amphibolite-facies metamorphism of the upper plate; a 96 m.y. U-Pb age (W. Hoppe, pers. comm.) of a tonalitic orthogneiss probably dates metamorphism and imbrication.

The lower-plate Chiwaukum Schist experienced 3 phases of folding and both Barrovian- and Buchan-type amphibolite-facies metamorphism in the Cretaceous; tight to isoclinal F2 folds dominate. Numerous ultramafic pods were faulted into the Chiwaukum prior to F2. Dioritic sills, presumably precursors of the 93-96 m.y. Big Jim phase of the Mt. Stuart Batholith (MSB), were intruded late during F2. F2 folds and sills were flattened during emplacement of the Big Jim phase. The main phase (86-93 m.y) of the MSB truncates the WPT and structures in both plates. Imbrication and metamorphism of the upper plate probably coincided with folding and metamorphism of the Chiwaukum, and may have overlapped intrusion of the Big Jim phase. However, final emplacement of the Ingalls postdated imbrication in the upper plate and F2 in the lower plate, as the WPT truncates imbricate thrusts and F2 axial surfaces. Obduction of the Ingalls also postdated emplacement of the pre-F2 ultramafic pods within the Chiwaukum. Thus, oceanic lithosphere and the Skagit core show a complex interaction.

Evolution of the eastern Coast Mountains, near Lillooet southwestern British Columbia

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(Sponsor: R.E. Beck)

Rocks in the eastern margin of the Coast Mountains, southwest of Lillooet, are mainly variably deformed and metamorphosed chert, argillite, basic volcanics, minor carbonate and ultramafics of the Middle Triassic to Lower Jurassic Bridge River Complex (BRC; C.J. Potter, 1983), Lower Cretaceous (Neocomian) and older (?) clastics of the Brew Group (BG), and Late Cretaceous and Tertiary granitic intrusions. Reconnaissance mapping and preliminary isotopic dating suggest the following evolution: (1) post-Toarcian (~175 Ma) disruption of BRC, typically producing chaotic "broken formation"; (2) post-Neocomian (~125 Ma) tight to isoclinal folding of BG forming in places large-scale flat-lying folds with southwest-dipping axial surfaces, and (?) congruent deformation in BRC; (3) intrusion and contact metamorphism of deformed BG by granitic rocks that nearby yield 60-70 Ma K-Ar ages; (4) eastward brittle overthrusting of BRC on BG and intrusions, possibly concomitantly with sub-horizontal ductile shearing, isoclinal folding and metamorphism to biotite garnet grade of lower-level BRC. Concordant mylonitized intrusions in the latter yield zircons with 40 Ma U-Pb and Pb-Pb ages; (5) juxtaposition of all units by high-angle faults that splay northwesterly off the north-south Fraser fault zone. Fission track data (R.R. Parrish, 1982) indicate major uplift prior to 30 Ma.

Since these rocks lie 180 km north of latitude 49° on the west side of the Fraser-Straight Creek dextral fault system, their evolution may bear on that of the higher metamorphic grade rocks in the core of the Northern Cascades.

Petrologic Evolution of the Late Cretaceous Nanaimo Basin: British Columbia and Washington

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The Late Cretaceous Nanaimo Basin formed within an orogenic collage, surrounded by the North Cascades, Coastal Plutonic Belt, Insular Belt and San Juan Island terranes. It may have developed as a pull-apart basin within a proto-Queen Charlotte transform zone or as an intramassif forearc basin.

Paleocurrent and petrographic data indicate that during early development of the basin, it was filled largely with debris rich in chert and subordinate argillaceous and intermediate-volcanic rock fragments from San Juan Island terranes, intermediate-volcanic and low-grade metamorphic rock fragments from the North Cascades and basic volcanic rock fragments and chert from the Insular Belt. As the basin evolved, input from these sources decreased and sedimentation into the basin was dominated by plutonic debris from the Coastal Plutonic Belt, with subordinate deposition of plutonic and intermediate- to silicic-volcanic debris from the Insular Belt.

Dominance of plutonic over volcanic debris derived from the Coastal Plutonic Belt suggests deep dissection. Contemporaneous volcanic rock fragments are conspicuously absent. A magmatic gap occurred in the southern Coastal Plutonic Belt during Nanaimo Basin development and the tectonic setting is characterized by a broad zone of right-lateral transcurrent faulting. These data suggest that subduction may have greatly slowed or ceased along the continental margin of British Columbia during the Late Cretaceous.

The geometry of the subducted Juan de Fuca Plate

ROBIN RIDDIHOUGH (Pacific Geoscience Centre, P.O. Box 6000, Sidney, B.C. Canada V8L 4B2)

There is good circumstantial, and some reasonable inferential, evidence that the subducting Juan de Fuca plate can be divided into a shallow dipping (~10°) upper section and a steeper dipping (30-40°) lower section. This places it in common with many subducted slabs which show some form of discontinuous geometry as they descent into the mantle.

A number of explanations for such geometry have been advanced. These range from the influence of accretion on the leading edge of the overlying plate to discrete events in the history of convergence such as changes in absolute velocity or the subduction of aseismic ridges. None of these explanations seems to be entirely satisfactory for the Juan de Fuca plate. This suggests that it may be a continuous dynamic process involving a combination of depth related phase changes, convergence rates and the age of the subducting lithosphere.

Queen Charlotte-Fairweather Transform Map

ROBIN RIDDIHOUGH, GARRY ROGERS and BILL PRICE, (Pacific Geoscience Centre, Box 6000, Sidney, B.C. V8L 4B2)

The region of transform interaction between the Pacific and America plates from the Aleutian trench to the Juan de Fuca Ridge triple junction and the adjacent offshore areas of the north-east Pacific Ocean are becoming the subject of increasing geoscientific interest.

Following the success of the Juan de Fuca plate map, we propose to produce a similar map for this region. A manuscript topographic/bathymetric base map at a scale of 1:2,000,000 has been prepared. Its corners are: 61°N, 150°W; 48°N, 145°W; 48°N, 123°W; 61°N, 121°W such that Anchorage is shown in the north-west and Victoria in the south-east. The projection is Lambert Conformal Conic chosen so that it will overlay the Juan de Fuca Map in the south.

We invite comments, advice and support on all aspects of the map and the project.

The Seismograph Network in British Columbia - 1983

G.C. ROGERS (Pacific Geoscience Centre, Earth Physics Branch, P.O. Box 6000, Sidney, B.C. Canada V8L 4B2)

In 1983 forty seismograph stations are being operated in British Columbia by three different agencies: the Earth Physics Branch at the Pacific Geoscience Centre (P.G.C.), the Department of Geophysics and Astronomy at the University of British Columbia (U.B.C.) and the British Columbia Hydro and Power Authority (B.C.H.). These include three international standard six component stations, twelve single component short period stations and three telemetered short period arrays. The P.G.C. and U.B.C. arrays interface and monitor the subduction region in the southwest corner of the province. They use digital telemetry with identical equipment. The B.C.H. array monitors the Mica and Revelstoke reservoir regions in eastern British Columbia. Most of the regional stations have been placed by P.G.C. or B.C.H. to provide short term monitoring of specific regions.

Structural Influence on Early Tertiary Sedimentary Basin Geometry, Southwestern Oregon

RYBERG, PAUL T. (Laboratory of Geotectonics, Department of Geosciences, University of Arizona, Tucson, AZ 85721) (Sponsor: P. L. Heller)

The geometry of sedimentary basins that developed during early Tertiary time in southwestern Oregon was controlled by synchronous deformation. Several major fault systems were active until 49 mybp, including the Bonanza, Safari, Powers-Agness, and Canyonville faults. These faults displace sedimentary rocks of early Eocene (Penutian) age, and are overlapped by middle Eocene (Ulatisian) sediments. The Bonanza Fault near Sutherlin, is a northwest-verging reverse/thrust fault with at least 1500 m dip separation. Highly deformed sedimentary beds of the early Eocene Roseburg Formation lie between several splays which branch off the main fault near Roseburg. The Safari Fault, south of Roseburg, trends northeastward with a steep linear trace. Locally exposed striated surfaces and displaced facies suggest 5-6 km of right-lateral strike-slip separation. The Powers-Agness Fault in the south-central coast range, is a steep north-south trending reverse fault, along which the western block has been uplifted at least 2000 m. Displaced Mesozoic thrust contacts and offset early Eocene sediments along the east-west trending Canyonville Fault, suggest a minimum of 30 km of right-lateral strike-slip separation.

Isopachs of the middle Eocene Tyee Formation suggest that although these faults were no longer active at the time of Tyee deposition, their relief still influenced the distribution of sediment along the southern margin of the basin. A minor amount of tectonic rotation may have been accomodated by these early Eocene faults, but at least 50° of clockwise rotation must have occurred after deposition of the Tyee Formation. Present paleomagnetic data are insufficient to distinguish differential tectonic rotations on either side of these major faults.

Revised Stratigraphy of the Deschutes basin, Oregon: Implications for the Neogene Development of the central Oregon Cascades

GARY A. SMITH
LAWRENCE W. SNEE (Both at: Dept. of Geology, Oregon State Univ., Corvallis, OR 97331)

Volcanic and epiclastic material of the Deschutes Fm. (DF) was derived from ancestral High Cascade volcanoes which subsided into an axial graben about 4.5 m.y.b.p. and were buried under younger volcanics. A mid Miocene base for the DF was based on fossils and a 16.3±3.0 m.y. K-Ar date on the Pelton basalt member (recalc. from Armstrong et al., 1975)*. A new $^{40}Ar/^{39}Ar$ date of 7.6± 0.3 m.y. (1σ) on the Pelton basalt is considered to be a more accurate age for this low-K, vapor-differentiated(?), unit which immediately underlies Late Miocene fossils. An angular unconformity separates the Pelton basalt from the underlying rocks, bearing mid-Miocene fossils, now assigned to the Simtustus formation (SF) which overlies, and is interbedded with, the Columbia River Basalt Group (CRBG). The DF volcanic episode thus represents only the period 7.5-4.5 m.y.b.p. when a large volume of pyroclastic material and lava was erupted in the central Oregon Cascades, in response to regional tension that culminated in the formation of the graben. Preservation of the Cascades volcanic record in adjacent non-marine basins is not complete. Deposition of SF was a result of aggradation caused by disruption of Columbia basin drainage by the CRBG. DF aggradation was a response to extraordinary pyroclastic volcanism in a semi-arid climate and preservation was assured by overlying, largely intrabasin-derived, lava flows. The approx. 8 m.y. hiatus in Deschutes basin stratigraphy does not represent Cascade quiescence, but rather improper conditions for preservation in the record.

*(Ref: Isochron/West, #13, p. 5-10)

Propagation as a Mechanism of Ridge Reorientation in the Juan de Fuca Area

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We present a revised model of tectonic evolution of the Juan de Fuca ridge by propagating rifting. The new model has three different relative rotation poles, covering the time intervals 17.0-8.5 m.y., 8.5-5.0 m.y., and 5.0 m.y. to the present. The rotation pole shifts at 8.5 and 5.0 m.y. imply clockwise shifts in the direction of relative motion of 10° to 15°. At each of these shifts, the pattern of propagation reorganizes, and the new ridges formed by propagation are at an orientation closer to orthogonal to the new direction of motion than the orientation of the pre-existing ridges. The model, containing a total of seven propagation sequences, shows excellent agreement with the anomaly data, except in areas complicated by the separate Explorer and Gorda plates. The agreement between model and data near the Explorer plate breaks down abruptly at an age of about 5 m.y., indicating that the probable cause of the rotation pole shift at that time was the separation of the Explorer plate from the Juan de Fuca plate.

Paleomagnetic evidence for 36° anticlockwise rotation of northern Ellesmere Island - possible key to solution of the Nares Strait problem

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K. OSADETZ (Institute of Sedimentary and Petroleum Geology, 3303 - 33 St. N.W., Calgary, Alta., T2L 2A7)

The early Permian Esayoo Formation (basalts) has been sampled at 12 sites (88 specimens) from two localities in the Van Royen Ridge and Hare Fiord areas. The localities are apparently from the same thrust sheet in the zone of Early Tertiary decollement (Eurekan Orogeny). Detailed alternating field and thermal demagnetization reveal well-grouped magnetizations with SE declinations and with upward inclinations (reversed polarity). The inclinations yield a palaeolatitude concordant with the Early Permian geomagnetic field for cratonic North America. The declinations indicate a 36° sinistral rotation of the beds. The rotation is in the correct sense to be related to the opening of Baffin Bay. If northern Ellesmere Island is assumed fixed relative to northern Greenland (i.e. no motion on Nares Strait), the opening of Baffin Bay and the Labrador Sea will account for only about one-third of the observed rotation. Most of the rotation seems to have occurred by strain within northern Ellesmere Island. The rotation could have been caused by shear along one or more sinistral transcurrent faults similar to that recently described by Mayr and de Vries. It could reflect deformation within northern Ellesmere Island which could together with the as yet undetermined crustal shortening in the Eurekan foldbelt, account for the inconsistency between the opening of Labrador Sea and the absence of evidence for substantial closure and shear along Nares Strait.

Pn Velocities and Station Delays in Washington

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Sixty four well recorded regional earthquakes within 1500 km of the Washington State seismograph network are analyzed to determine Pn velocities and station delays in various subregions of the State. Apparent velocities across the subnetworks are used to distinguish upper mantle arrivals from crustal arrivals. The crossover distance is roughly 200 km. The time term method is then used to determine the upper mantle velocity of the region and the relative station delays due to the variability of crustal structure in the region. Comparison of preliminary results for the eastern vs. the western side of the Cascade Range indicates a marked change in velocity from 8.3 km/sec east of the Cascades to 7.8 km/sec west of the Cascades. This result is consistent with previous studies but represents a more significant result because of the substantially increased data set due to both more stations and a larger number of events. Analysis of azimuthal effects and variations within subregions is being carried out in order to make comparisons with previously suggested structure models and to improve our knowledge of the deep crust and upper mantle structure.

Geophysical Year

A date at the end of an entry indicates the issue of *Eos* in which a full meeting announcement was run.

A list of abbreviations used in the Geophysical Year calendar appears at the end of the calendar.

Future AGU Meetings:

Fall Meetings

Dec. 3–7, 1984, San Francisco
(Abstracts due mid-September 1984)

Dec. 9–13, 1985, San Francisco
(Abstracts due mid-September 1985)

Spring Meetings

May 14–17, 1984, Cincinnati

May 27–31, 1985, Baltimore
(Abstracts due early March 1985)

Chapman Conferences

The Magnetospheric Polar Cap
August 6–9, 1984, Fairbanks
(Abstracts due May 1, 1984)

Vertical Crustal Motion:
Measurement and Modeling
October 22–26, 1984, Harpers Ferry, W. Va.
(Abstracts due August 1, 1984)

1984

April 24–26 Fourth Annual Front Range Branch **Hydrology Days,** Fort Collins, Colo. (H. J. Morel-Seytoux, Dept. of Civil Engineering, Colorado State Univ., Fort Collins, CO 80523; tel. 303-491-5448 or 8549.) (Nov. 22, 1983.)

April 24–27 Pacific Conference on **Marine Technology** (PACON 84), Honolulu, Hawaii. Sponsors, Marine Technology Society, **AGU.** (PACON 84, Center for Engineering Research, Univ. of Hawaii at Manoa, Honolulu, HI 96822, tel.: 808-948-7338 or 7449.) (Aug. 16, 1983.)

April 26–27 Sixth Annual Texas A&M Geodynamics Research Program Symposium on **Collision Tectonics: Deformation of Continental Lithosphere,** College Station, Tex. Sponsors, Inter-Union Commision on the Lithosphere, NASA, and the Commission on Marine Geophysics of IAPSO. (Texas A&M Geodynamics Office, College Station, TX 77843–3114; tel. 409-845-8477.)

April 29–May 4 Penrose Conference on Processes and Products of Multistage **Melting and Metasomatism in the Mantle,** Gold Canyon Ranch, Ariz. Sponsors, GSA and USGS. (J. E. Pike, USGS, 345 Middlefield Rd., MS 75, Menlo Park, CA 94025.) (Oct. 25, 1983.)

April 30–May 3 International Association for **Great Lakes Research** Annual Conference, St. Catherines, Ontario, Canada. (J. Teresmae, Dept. Geological Science, Brock Univ., St. Catherines, Ontario L2S 3A1, Canada; tel.: 416-688-5550.)

April 30–May 3 30th Annual Technical Meeting: **Environmental Integration Technology** Today for a Quality Tomorrow, Orlando, Fla. Sponsor, Institute of Environmental Sciences. (Institute for Environmental Sciences, 940 E. Northwest Hwy., Mount Prospect, IL 60056; tel.: 312-255-1561.)

April 30–May 4 Penrose Conference on Structural Styles and Deformational Fabrics of **Accretionary Complexes,** Eureka/Arcata, Calif. Sponsor, GSA. (Western Experience, 2450 Central Ave., Suite P-2, Boulder, CO 80303; tel. 303-449-3352.)

May-June 12th International Congress on **Irrigation and Drainage,** Fort Collins, Colo. (ICID, 48 Nyaya Marg, Chanakyapuri, New Delhi 110012, India.)

May 7–9 Third Symposium on **Arctic Air Chemistry,** Downsview, Ontario, Canada. (L. A. Barrie, Atmospheric Environment Service, 4905 Dufferin St., Downsview, Ontario M3H 5T4, Canada, tel.: 416-667-4785; or K. A. Rahn, Graduate School of Oceanography, Univ. of Rhode Island, Narragansett, RI 02882–1197, tel.: 401-792-6254.) (Aug. 23, 1983.)

May 14–16 **Geological Assoc. of Canada** and **Mineralogical Assoc. of Canada** Joint Annual Meeting, London, Ontario, Canada. (N. D. MacRae, Dept. of Geology, Univ. of Western Ontario, London, Ontario N6A 5B7, Canada.)

May 14–17 **AGU Spring Meeting,** Cincinnati, Ohio. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

May 20–23 **U. S. SPOT Symposium,** Scottsdale, Ariz. Sponsor, SPOT IMAGE Corporation. (Nadine Binger, SPOT IMAGE Corporation, 1150 17th Street NW, Suite 307, Washington, DC 20036; tel.: 202-293-1650.) (April 10, 1984.)

May 20–25 International Symposium on Deep Observation and Sampling of the **Continental Crust Through Drilling,** Tarrytown, N. Y. (Barry Raleigh, Director, Lamont-Doherty Geological Observatory, Palisades, NY 10964; tel.: 914-359-2900.)

May 21–23 International **Groundwater Symposium** on Groundwater Resources Utilization and Contaminant Hydrogeology, Montreal, Canada. Sponsors, Canadian National Chapter of the International Association of Hydrogeologists and the Canadian Water Well Association. (A. Kohut, Chairman, International Groundwater Symposium Montreal '84, Ministry of the Environment, 765 Broughton St., Victoria, B. C., V8V 1X5, Canada.)

May 21–23 Symposium on **Climate:** History, Periodicity, and Predictability, N.Y. (John E. Sanders, Dept. of Geology, Barnard College, Columbia Univ., New York, NY 10017; tel.: 212-280-4312.) (Aug. 23, 1983.)

May 21–23 Ninth Conference on **Weather Modification,** Park City, Utah. Sponsor, American Meteorological Society. (Edward Hindman, Dept. Atmospheric Science, Colorado State Univ., Ft. Collins, CO 80523; tel. 303-491-8311.)

May 23–25 Fourth National Symposium and Exposition on **Aquifer Restoration** and Groundwater Monitoring, Columbus, Ohio. Sponsor, National Water Well Association. (NWWA, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

May 23–25 Workshop on **Precipitation Enhancement,** Park City, Utah. Sponsors, National Science Foundation and American Meteorological Society. (Roscoe Braham, Dept. of Geophysical Sciences, Univ. of Chicago, Chicago, IL 60637; tel. 312-962-8123/8124.)

May 24–26 Symposium on the **History of Soil and Water Conservation,** Columbia, Mo. Sponsors, Missouri Cultural Heritage Center at the Univ. of Missouri, the Agricultural History Society, and the Soil Conservation Service of the U.S. Dept. of Agriculture. (Susan Flader, Dept. of History, Univ. of Missouri, Columbia, MO 65211, tel.: 314-882-2481 or 314-442-1058; or Douglas Helms, Historian, Soil Conservation Service, P.O. Box 2890, Washington, DC 20013, tel.: 202-382-0042.)

May 28–June 2 12th International Congress on **Irrigation and Drainage,** Fort Collins, Colo. Sponsors, U.S. Committee on Irrigation, Drainage, and Flood Control (UCIDFC), AGU. (UCIDFC, P.O. Box 15326, Denver, CO 80215.)

May 29–31 **Urban Water '84—A Time For Renewal,** Baltimore, Md. Sponsor, American Society of Civil Engineers Water Resources Planning and Management Division. (Harold Day, College of Environmental Science, Univ. of Wisconsin at Green Bay, Green Bay, WI 54301; tel. 414-465-2250.)

May 29–June 1 Joint Meeting of the 11th Annual Meeting of the **Canadian Geophysical Union** and the 18th Annual Congress of the **Canadian Meteorological and Oceanographic Society,** Halifax, Nova Scotia, Canada. (S. D. Smith or H. R. Jackson, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2.) (Aug. 30, 1983.)

June 4–6 International Conference on Inverse Problems of **Acoustic and Elastic Waves,** Ithaca, N. Y. Sponsor, Cornell University. (Yih-Hsing Pao, Department of Theoretical and Applied Mechanics, Cornell University, Ithaca, NY 14853; tel.: 607-256-2345.)

June 4–7 Symposium on **Climate and Paleoclimate of Lakes, Rivers, and Glaciers,** Igls, Austria. Sponsor, International Commission on Climate, IAMAP. (M. Kuhn, Institut fur Meteorologie und Geophysik, Schoepfstrasse 41, A-6020 Innsbruck, Austria.) (Oct. 25, 1983.)

June 4–8 IWRA Seminar on **River Basin Strategy,** Linköping, Sweden. (U. Lohm, Water Theme, Linköping Univ., S-58183, Linköping, Sweden.) (Oct. 18, 1983.)

June 4–8 Seventh International Conference on **Atmospheric Electricity,** Albany, N. Y. Sponsors, IAMAP International Commission on Atmospheric Electricity, AMS, and **AGU.** (R. E. Orville, Atmospheric Electricity Conference, E.S. 214, 1400 Washington Ave., SUNY, Albany, NY 12222; tel.: 518-457-3987.) (July 26, 1983.)

June 4–8 Third International Conference on **Urban Storm Drainage,** Göteborg, Sweden. Sponsors, IAHR and International Association on Water Pollution Research. (P. Malmqvist, c/o Dept. of Hydraulics, Chalmers Univ. of Technology, S-412 96 Göteborg, Sweden.)

June 6–9 Second American Conference on **Ice Nucleating Bacteria,** Flagstaff, Ariz. (Ralph M. Bilby Research Center, Box 6013, Northern Arizona Univ., Flagstaff, AZ 86011.) (Nov. 15, 1983.)

June 10–15 65th Annual Meeting of the **American Association for the Advancement of Science (Pacific Division),** San Francisco, Calif. (John H. Vann, Dept. of Geography, California State Univ., Hayward, CA 94542; tel.: 415-881-3193.) (Jan. 31, 1984.)

June 11–12 Fifth European **Conference on Environmental Pollution,** Amsterdam, The Netherlands. (V. M. Bhatnager, Box 1779, Cornwall, Ontario K6H 5V7, Canada.)

June 11–13 Symposium on Critical Assessment of **Forecasting in Western Water Resource Management,** Seattle, Wash. Sponsors, AWRA and **AGU.** (G. R. Minton, President, Resource Planning Assoc., 113 Lynn St., Seattle, WA 98109; tel.: 206-282-1681.) (June 28, 1983.)

June 17–23 Second International **Tsunami Conference,** Las Vegas, Nev. (Tsunami Society, Box 8523, Honolulu, HI 96815.)

June 18–22 Fifth International Conference on **Finite Elements in Water Resources,** Burlington, Vt. Sponsors, Univ. of Vermont, **AGU.** (J. P. Laible, Dept. of Civil Engineering and Mechanical Engineering, Univ. of Vermont, Burlington, VT 05405; tel.: 802-656-3800.)

June 19–21 Third International Conference on **Marine Simulation,** Rotterdam, The Netherlands. Sponsor, Maritime Research Institute Netherlands. (Secretariat MARSIM 84, c/o Maritime Research Institute Netherlands, P.O. Box 1555, 3000 BN Rotterdam, The Netherlands.)

June 23–30 Penrose Conference on **Melanges of the Appalachian Orogen,** Newfoundland, Canada. Sponsor, GSA. (Brenna E. Lorenz, Dept. of Earth Sciences, Memorial Univ. of Newfoundland, St. Johns, Newfoundland A1B 3X5 Canada.) (June 28, 1983.)

June 24 International Conference on **Geomembranes,** Denver, Colo. (A. I. Johnson, Woodward-Clyde Consultants, 7600 E. Orchard Rd., Englewood, CO 80111; tel.: 303-694-2770.)

June 24 International Symposium on **Impermeable Barriers for Soil and Rock,** Denver, Colo. (A. I. Johnson, Woodward-Clyde Consultants, 7600 E. Orchard Rd., Englewood, CO 80111; tel.: 303-694-2770.)

June 24–30 14th International Conference on **Mathematical Geophysics,** Loen, Norway. (L. Tronrud, NTNF/NORSAR, P.O. Box 51, N-2007 Kjeller, Norway; telex: 18147 kcin.)

June 25–27 **Rock Mechanics** in Protection and Productivity, 25th U.S. Symposium on Rock Mechanics, Evanston, Ill. Sponsor, **AGU.** (Charles H. Dowding, Dept. of Civil Engineering, Northwestern Univ., Evanston, IL 60201; tel.: 312-492-7270.) (Sept. 18, 1983.)

June 25–July 7 **ICSU Committee on Space Research** 25th Meeting, Graz, Austria. (Richard C. Hart, Space Science Board, JH-828, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418.)

June 25-July 7 Symposium on **Space Observations for Climate Studies,** Graz, Austria. Sponsor, World Climate Program. (S. Ruttenberg, Secretary, COSPAR Commission A, NCAR, Boulder, CO 80307.) (July 19, 1983.)

June 26–28 Symposium of the Achievements of the **International Magnetospheric Study,** Graz, Austria. Sponsor, ICSU Scientific Committee on Solar-Terrestrial Physics. (J. G. Roederer, Geophysical Institute, Univ. of Alaska, Fairbanks, AK 99701.)

June 26–28 1984 International Conference on **Lightning and Static Electricity,** Orlando, Fla. Sponsors, NOAA, IEEE, SAE-AE4 Committee, and several military and civilian air transportation agencies in the U.S. and UK. (J. J. Fisher, Conference Chairman, U.S. Naval Air Systems Command, P.O. Box 15036, Arlington, VA 22215; tel.: 202-692-7822; or G. Odam, European Coordinator, Royal Aircraft Establishment, Farnborough, Hants, GU14 6TD UK; tel.: 0252-24461, ext. 2638.) (Sept. 6, 1983)

June 26–28 International Symposium on Deep Structure of the **Continental Crust:** Results from Reflection Seismology, Ithaca, N.Y. Sponsors, Cornell University Institute for the Study of the Continents, **AGU,** GSA, IASPEI, International Lithosphere Program, SEG. (Muawia Barazangi, Conference Coordinator, Dept. of Geological Sciences, Cornell Univ., Ithaca, NY 14853; tel.: 607-256-6411 or telex: 937478.)

July 2–5 Symposium on the Physics of the **Magnetosphere-Ionosphere Connection,** Graz, Austria. Sponsor, Committee on Space Research of ICSU. (E. R. Schmerling, EE-8, NASA Headquarters, Washington, DC 20546.) (Dec. 6, 1983.)

July 5–6 Second **Symposium on Plasma Double Layers and Related Topics,** Innsbruck, Austria. (R. Schrittwieser, Inst. for Theoretical Physics, Univ. of Innsbruck, Sillgasse 8, A-6020 Innsbruck, Austria.)

July 9–13 International Symposium on **Space Techniques for Geodynamics,** Sopron, Hungary. Sponsors, Hungarian Academy of Sciences and IAG/COSPAR Joint Commission on the International Coordination of Space Techniques for Geodesy and Geodynamics. (Ch. Reigber, Deutsches Geodätisches Forschungsinstitut, Abt. I, Marstallplatz 8, D-8000 Munich 22, FRG.)

July 9–13 **Longitude Zero,** Greenwich, UK. Sponsors, International Union for the History and Philosophy of Science and the International Astronomical Union. (Conference Officer, "Longitude Zero" Symposium, National Maritime Museum, Greenwich, London SEO 9NF, UK.) (Nov. 15, 1983.)

July 10–14 **The Case for Mars II,** Boulder, Colo. Sponsor, Mars Institute of the Planetary Society. (Helen Hart, Laboratory for Atmospheric and Space Physics, Univ. of Colorado, Boulder, CO 80309; tel.: 303-492-8822; Carol Stoker or Tom Meyer, Case for Mars, P.O. Box 4877, Boulder, CO 80306; tel.: 303-494-8144.) (Dec. 20, 1983.)

July 18–20 **Seismic Deconvolution Workshop,** Vail, Colo. Sponsor, SEG. (Sven Treitel, Amoco Production Co., Research Center, P.O. Box 591, Tulsa, OK 74102.) (Feb. 7, 1984.)

July 19–25 Symposium on Wave Breaking, Turbulent Mixing, and Radio Probing of the **Ocean Surface,** Sendai, Japan. (O. M. Phillips, Dept. of Earth and Planetary Sciences, Johns Hopkins Univ., Baltimore, MD 21218; tel.: 301-338-7036.)

July 21–28 Eighth World Conference on **Earthquake Engineering,** San Francisco, Calif. Sponsor, Earthquake Engineering Research Institute (EERI), **AGU.** (J. Penzien, Chair-8WCEE, EERI, 2620 Telegraph Ave., Berkeley, CA 94701.)

July 23–25 Summer **Computer Simulation** Conference, Boston, Mass. Sponsor, Society for Computer Simulation. (W. D. Wade, 1984 SCSC Program Chairman, Wade Engineering P.C., P.O. Box 849, Huntington, NY 11743; tel.: 516-271-6073.)

July 23–26 11th International Symposium on **Urban Hydrology,** Hydraulics, and Sediment Control, Lexington, Ky. Sponsor, Univ. of Kentucky. (F. Haden, *Coordinator,* Office of Continuing Education/Engineering, 223 Transportation Research Bldg., Univ. of Kentucky, Lexington, KY 40506–0043; tel.: 606-257-3972.) (Nov. 15, 1983.)

July 24–26 **Water Rights** Specialty Conference, Flagstaff, Ariz. Sponsors, Ground Water Committee and Surface Water Committee of the ASCE Irrigation and Drainage Division. (Kenneth G. Renard, Southwest Watershed Research Center, 2000 E. Allen Rd., Tucson, AZ 85719; tel.: 602-629-6381.)

July 26–27 A Joint Workshop of the Committee on **Climatic Changes and the Ocean** and the Joint Scientific Committee for **World Climate Research** Panel, Sendai, Japan. (O. M. Phillips, Dept. Earth and Planetary Sciences, Johns Hopkins Univ., Baltimore, MD 21218; tel.: 301-338-7036.)

July 30–August 2 Seminar on **Water Management Practice,** Zaria, Nigeria. Sponsors, International Association for Hydraulic Research and UNESCO. (Gunnar Lindh, Dept. of Water Resources Engineering, Lund Institute of Technology, Fack 725, S-220 07 Lund, Sweden.) (Dec. 6, 1983.)

July 30–August 3 **Eurogeophysics Assembly,** Louvain-la-Neuve, Belgium. Sponsor, European Geophysical Society. (G. M. Brown, Dept. of Physics, Univ. College of Wales, Aberystwyth, Wales, UK.) (Dec. 20, 1983.)

July 31–Aug. 2 Fourth International Symposium on **Stochastic Hydraulics,** Univ. of Illinois, Urbana-Champaign. Sponsors, IAHR and AGU. (Ben C. Yen, Wilson H. Tang, or Glenn E. Stout, Dept. of Civil Eng., Univ. of Illinois, 208 N. Romine St., Urbana, IL 61801; tel.: 217-333-0687 or 333-0536.) (Nov. 8, 1983.)

July 31-August 3 Workshop on **Fission Track Dating,** Troy, N. Y. Sponsors, General Electric R&D Lab., SUNY at Albany, and Rensselaer Polytechnic Institute. (Donald S. Miller, Dept of Geology, Rensselaer Polytechnic Institute, Troy, NY 12181.)

Aug. 4–14 27th **International Geological Congress,** Moscow, USSR. Sponsors, USSR National Committee for Geology, IUGS. (Organizing Committee of the 27th IGC, Institute of the Lithosphere, 22, Staromonetny, Moscow. 109180, USSR.)

Aug. 6–9 Chapman Conference on the *Magnetospheric Polar Cap, Fairbanks, Alaska.* (Polar Cap Meeting, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.) (Jan. 24, 1984.)

Aug. 12–16 20th Annual AWRA Conference and Symposium, Washington, D. C. (Arlene Dietz, U.S. Army Corps of Engineers, Institute for Water Resources, Casey Bldg., Fort Belvoir, VA 22060; tel.: 703-355-2368.) (Aug. 16, 1983.)

Aug. 13–17 12th International **Laser Radar** Conference, Aix-en-Provence, France. Sponsors, IAMAP and AMS. (G. Megie or J. P. Granier, Service D'Aéronomie du CNRS, 12th International Laser Radar Conference, BP 3, 91370-Verrières le Buisson, France.) (Nov. 8, 1983.)

Aug. 14–17 Specialty Conference on **Water for Resource Development,** Coeur d'Alene, Idaho. Sponsor, Hydraulics Division of ASCE. (Harry Tuvel, American Society of Civil Engineers, 345 E. 47th St. New York, NY 10017–2398; tel.: 212-705-7494.)

Aug. 21–29 International **Radiation Symposium** '84 (IRS), Perugia, Italy. Sponsor, IAMAP Radiation Commission. (Giorgio Fiocco, Chairman, IRS '84, Dipartimento di Fisica, Città Universitaria, 00185 Rome, Italy; telex: INFNRO 613255.)

Aug. 22–26 Field Conference on Open System **Behavior in Magmatic Evolution:** Petrological, Geochemical, and Geophysical Constraints, Taos, N. Mex. Sponsor, Institute for the Study of Earth and Man. (Mike Dungan, Dept. of Geological Sciences, Southern Methodist University, Dallas, TX 75275; tel.: 214-692-2750.) (Jan. 17, 1984.)

Aug. 26–29 **Geothermal Resources Council** 1984 Annual Meeting, Reno, Nev. (Geothermal Resources Council, P.O. Box 1350, Davis, CA 95617; tel.: 916-758-2360.) (Feb. 7, 1984.)

Aug. 26–31 Seventh **Australian Geological Convention,** Sydney, Australia. Sponsor, Geological Society of Australia. (Secretary 7 AGC, P.O. Box 383, North Ryde, NSW, Australia 2113.) (Nov. 29, 1983.)

Aug. 27–31 Seventh IAHR **Symposium on Ice,** Hamburg, Germany. (J. Schwarz, Ice Engineering Div., Hamburgische Schiffbau-Versuchanstalt GmbH., P.O. Box 600 929, 2000 Hamburg, FRG.) (Nov. 22, 1983.)

Aug. 27–Sept. 6 General Assembly of **URSI,** Florence, Italy. (Vito Cappellini, IROE, Via Panciatichi 64, 50127 Firenze, Italy.) (Dec. 27, 1983.)

Sept. 3–7 Quadrennial **Ozone Symposium,** Halkidiki, Greece. Sponsors, IAMAP International Ozone Commission (IOC), Commission of the European Communities, the Academy of Athens, and WMO. (Christos S. Zerofos, Chairman, Local Organizing Committee, Physics Dept., Campus Box 149, Univ. of Thessaloniki, Thessaloniki, Greece. Send copy of information request to C. D. Walshaw, Secretary, IOC, Clarendon Laboratory, Oxford Univ., Parks Rd., Oxford, OX1 3PU, UK.)

Sept. 10–12 **Oceans 84** Conference and Exhibition, Washington, D. C. Sponsors, Marine Technology Society, **AGU,** and Institute of Electrical and Electronics Engineers/Oceanic Engineering Society. (Oceans 84 Technical Program Committee, 1730 M St. N.W., Suite 412, Washington, DC 20036.) (Nov. 29, 1983.)

Sept. 10–14 International Symposium on **Hydromechanical Balances of Fresh Water Systems,** Stockholm/Uppsala, Sweden. Sponsors, Swedish Natural Science Research Council, UNESCO, and IAHS. (M. Falkenmark, Exec. Sec. NFRS, Comm. for Hydrology, Box 6711, S-11385 Stockholm, Sweden.)

Sept. 12–14 Seminar on Degradation, Retention, and Dispersion of **Pollutants in Groundwater,** Copenhagen, Denmark. Sponsor, International Association on Water Pollution Research and Control. (Erik Arvin, Dept. of Environmental Engineering, Building 115C, Technical Univ. of Denmark, DK-2800 Lyngby, Denmark.) (Dec. 13, 1983.)

Sept. 20–21 **International Symposium on Environmental Pollution,** Site To Be Announced. (V. M. Bhatnager, Box 1779, Cornwall, Ontario K6H 5V7, Canada.)

Sept. 24–25 Seminar: Enhanced **Biological Removal of Phosphorus From Wastewater,** Paris, France. Sponsor, International Association on Water Pollution Research and Control. (Michel Florentz, Phosphorus Seminar, Anjou-Recherche, 52, Rue d'Anjou, 75384 Paris Cedex 08, France; Tel.: 266-91-50; telex: Geneaux 280 332 F.) (Sept. 6, 1983.)

Sept. 24–26 **International Water Well Exposition,** Las Vegas, Nev. Sponsor, National Water Well Association. (National Water Well Association, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

Sept. 24–28 SLEADS (Salt Lakes, Evaporites, Aeolian Deposits) Workshop on **Cenozoic Salt Lakes and Arid Zone** Hydrology, Geochemistry, Stratigraphy, and Paleo-environments, *Mathoura, New South Wales, Australia.* Sponsor, the Australian National University. (J. M. Bowler, Dept. of Biogeography and Geomorphology, Research School of Pacific Studies, Australian National University, GPO Box 4, Canberra 2601, Australia.) (March 27, 1984.)

Sept. 26–28 Seventh National **Groundwater Quality** Symposium, Las Vegas, Nev. Sponsor, National Water Well Association. (NWWA, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

Oct. 1–5 International Symposium on Recent Investigations in the **Zone of Aeration,** Munich, FRG. Sponsor, Technical Univ. of Munich. (P. Udluft, RIZA Symposium, Institut für Wasserchemie der TU München, Marchioninistr. 17, D-8000 Munich 70, FRG.) (Dec. 20, 1983.)

Oct. 1–6 **European Seismological Commission,** Moscow. (Organizing Committee, ESC, Soviet Geophysical Committee, Molodezhnaya 3, 117 296 Moscow, USSR.)

Oct. 3–5 Symposium on **Meteorology and Oceanography of Northern High Latitudes,** Anchorage, Alaska. Sponsors, American Meteorological Society and AAAS. (Stuart Bigler, National Weather Service, 701 C St., P.O. Box 23, Anchorage, AK 99513.) (March 6, 1984.)

Oct. 8–11 **World Conference on Remote Sensing,** Bayreuth, FRG. Sponsors, Univ. of Bayreuth, Texas Christian Univ. Center for Remote Sensing and Energy Research, and International Society of Toxicological and Environmental Chemists. (Leo W. Newland, Director, Environment Sciences Program, Texas Christian Univ., Fort Worth, TX 76129; tel.: 817-921-7271.) (Feb. 7, 1984.)

Oct. 10–12 **Seismological Society of America Eastern Section 56th Annual Meeting,** St. Louis, Mo. (Robert B. Herrmann, Dept. of Earth and Atmospheric Sciences, St. Louis Univ., P.O. Box 8099, St. Louis, MO 63156; tel.:314-658-3120.)

Oct. 10–13 **New Mexico Geological Society** 35th Annual Field Conference, Taos, N. Mex. (R. Riecker, General Chairman, Los Alamos National Laboratory, Mail Stop D446, Earth and Space Sciences Div., Los Alamos, NM 87545.) (Nov. 1, 1983.)

Oct. 16–19 International Symposium on **Lake and Watershed Management:** Local Involvement, McAfee, N.J. Sponsor, North American Lake Management Society. (Harry Gibbons, Jr., Dept. of Civil and Environmental Engineering, Washington State Univ., Sloan Hall 141, Pullman, WA 99164–2912.) (March 6, 1984.)

Oct. 17–19 **AIPG** Annual Meeting, Orlando, Fla. (Bobby J. Timmons, General Chairman, Timmons Associates, P.O. Box 50006, Jacksonville, FL 32250; tel.: 904-246-4535.)

Oct. 22–26 **Chapman Conference on Vertical Crustal Motion:** Measurement and Modeling, Harpers Ferry, W. Va. Sponsor, AGU. (Vertical Motion Meeting, AGU, 2000 Florida Ave., N.W., Washington, DC 20009; telephone 202-462-6903 or toll-free 800-424-2488.)

Oct. 30–Nov. 3 Symposium on Relationships Between **Climate of China and Global Climate**—Past, Present, and Future, Peking, China. Sponsors, Academia Sinica, International Association of Meteorology and Atmospheric Physics (IAMAP), American Meteorological Society. (Jih-Ping Chao, Institute of Atmospheric Physics, Academia Sinica, Beijing, China.) (March 27, 1984.)

Oct. 31–Nov. 7 **Regional Assembly of IASPEI,** Hyderabad, India. (Mohan L. Gupta, Organizing Committee, IASPEI Regional Assembly, National Geophysical Research Institute, Hyderabad-500 007, India; telex: 155-478 NGRI IN; cable: Geophysics.) (Aug. 23, 1983.)

Nov. **Mexican Geophysical Union Annual Meeting,** La Paz, Baja California Sur, Mexico.

Meetings (cont. on p. 332)

Meetings (cont. from p. 331)

(cont. from p. 331)

(Union Geofisica Mexicana, A.C., Comite Organizador Reunion 1984, Apartado Postal 1805, Ensenada 22800, B.C.N. Mexico.)

Nov. 5–8 **GSA Annual Meeting,** Reno, Nev. (Jean Latulippe, GSA, P.O. Box 9140, Boulder, CO 80301; tel.: 303-447-2020.)

Nov. 12–17 **Water for South Africa,** Johannesburg, South Africa. Sponsors, National Water Well Association and the Borehole Water Association of Southern Africa. (David M. Nielsen, Conference Coordinator, NWWA, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.) (Dec. 13, 1983.)

Dec. 3–7 **AGU Fall Meeting,** San Francisco. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Dec. 16–21 International **Chemical Congress** of Pacific Basin Societies, Honolulu, Hawaii. Sponsors, ACS, Chemical Institute of Canada, and Chemical Society of Japan. (PAC CHEM '84, Meetings and Divisional Activities Dept., ACS, 1155 16th St., N.W., Washington, DC 20036; tel.: 202-872-4396; PAC CHEM '84, Chemical Institute of Canada, 151 Slater St., Suite 906, Ottawa, Ontario K1P 5H3, Canada; tel.: 613-233-5623; PAC CHEM '84, Chemical Society of Japan, 1–5, Kanda-Surugadai, Chiyoda-ku, Tokyo 101, Japan; tel.: 03–292–6161.) (Sept. 13, 1983.)

Dec. 28–31 Fourth International Conference on **Applied Numerical Modelling,** Tainan, Taiwan. (S. Y. Wang, School of Engineering, Univ. of Mississippi, University, MS 38677; tel.: 601-232-7219.)

1985

Jan. 7–12 17th International Congress on **Hydrogeology of Rocks of Low Permeability,** Tucson, Ariz. Sponsors, International Association of Hydrogeologists, AGU. (E. S. Simpson, Dept. of Hydrology and Water Resources, College of Engineering, Univ. of Arizona, Tucson, AZ 85721.)

March 10–15 American Society of Photogrammetry and American Congress on **Surveying and Mapping** National Meeting, Washington, D.C. (Willard A. Kuncis, 4415 Jensen Pl., Fairfax, VA 22032; tel.: 703-425-8790.)

April 1–4 **European Union of Geosciences** Biennial Meeting, Strasbourg, France. (Organizing Committee, Dept. of Earth Sciences, Univ. of Cambridge, Downing St., Cambridge CB2 3EQ, UK.)

April 9–11 Fifth Annual Front Range Branch **Hydrology Days,** Fort Collins, Colo. (H. J. Morel-Seytoux, Dept. of Civil Engineering, Colorado State Univ., Fort Collins, CO 80523; tel.: 303-491-5448 or 8549.)

May 27–31 **AGU Spring Meeting,** Baltimore, Md. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Summer Colloquium on Comparative Study of **Magnetospheric Systems,** France. (Dominique Le Quéau and Bent Møller-Pedersen, DASOP, Observatoire de Meudon, F 92195, Meudon Principal Cedex, France; Telex: 200 590 CNET OBS.) (Aug. 9, 1983.)

June 9–15 IWRA Fifth World Congress, Brussels, Belgium. (Fifth World Congress On Water Resources, Brussels International Conference Centre, Parc des Expositions, Tentoonstellingspark, B-1020 Brussels, Belgium; tel.: 32–2–478–48–60; telex: 23–643.) (Aug. 30, 1983.)

June 16–21 Third International Symposium on Analysis of **Seismicity and Seismic Risk,** Liblice, Czechoslovakia. (Z. Schenkova, Geophysical Institute, Bocni II, 14131 Prague 4, Czechoslovakia.)

June 26–28 **U.S. Symposium on Rock Mechanics,** Rapid City, S. Dak. Sponsor, South Dakota School of Mines and Technology. (Eileen Ashworth, Chairman, 26th U.S. Symposium on Rock Mechanics, Dept. of Mining Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701–3995; tel.: 605-394-2344.)

Aug. 5–16 **IAMAP/IAPSO** Joint Assembly, Honolulu, Hawaii. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Aug. 5–17 Symposium on **Magnetic Anomalies** over the Margins of Continents and Plates, Prague, Czechoslovakia. Sponsor, International Association of Geomagnetism and Aeronomy. (William J. Hinze, Dept. of Geosciences, Purdue Univ., West Lafayette, IN 47907; tel.: 317-494-5982.) (Feb. 7, 1984.)

Aug. 19–23 Sixth **Gondwana Symposium,** Columbus, Ohio. Sponsor, GSA. (D. Elliot, Ohio State Univ., Institute of Polar Studies, 103 Mendenhall, 125 South Oval Mall, Columbus, OH 43210.)

Aug. 19–30 **23rd General Assembly of IASPEI,** Tokyo, Japan. (Ryosuke Sato, Secretary-General of the 23rd General Assembly of IASPEI, c/o Inter Group Corp., Akasaka Yamakatsu Bldg., 8–5–32, Akasaka, Minato-ku, Tokyo 107, Japan; tel.: Tokyo (03) 479-5311.)

Sept. 16–21 Symposia on **Potassic Volcanism** and **Etna Volcano,** Catania, Italy. Sponsor, IAVCEI. (G. Frazzetta and G. Lanzafame, Istituto Internazionale di Vulcanologia, V.le R. Margherita, 6, Catania, Italy.) (Dec. 27, 1983.)

Sept. 17–21 **AIPG** Annual Meeting, St. Paul, Minn. (Robert E. Prendergast, General Chairman, Geotechnical Engineering Corp., 1925 Oakcrest Ave., Roseville, MN 55113; tel.: 612-636-7744.)

Oct. 14–17 **GSA** Annual Meeting, Boston, Mass. (Jean Latulippe, GSA, P.O. Box 9140, Boulder, CO 80301; tel.: 303-447-2020.)

Dec. 9–13 **AGU Fall Meeting,** San Francisco. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

1986

June, 1986 Conference on **Study and Mitigation of Hazards,** San Martin. Sponsor, Tsunami Society. (Hazards Conference, Box 60536, Las Vegas, NV 89160.)

AAAS American Association for the Advancement of Science
AAPG American Association of Petroleum Geologists
ACS American Chemical Society
AIPG American Institute of Professional Geologists
AMS American Meteorological Society
ASCE American Society of Civil Engineers
AWRA American Water Resources Association
GSA Geological Society of America
IAG International Association of Geodesy
IAGA International Association of Geomagnetism and Aeronomy
IAHR International Association for Hydraulic Research
IAHS International Association of Hydrological Sciences
IAMAP International Association of Meteorology and Atmospheric Physics
IAPSO International Association for the Physical Sciences of the Ocean
IASPEI International Association of Seismology and Physics of the Earth's Interior
IAVCEI International Association of Volcanology and Chemistry of the Earth's Interior
ICSU International Council of Scientific Unions
IUGG International Union of Geodesy and Geophysics
IUGS International Union of Geological Sciences
IWRA International Water Resources Association
MSA Mineralogical Society of America
SEG Society of Exploration Geophysicists
SEPM Society of Economic Paleontologists and Mineralogists
URSI International Union of Radio Science
WMO World Meteorological Organization

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Aeronomy

0460 Tides, Waves and Winds
REPLY TO HINES' "COMMENTS ON "POTENTIAL" TREATMENT OF ATMOSPHERIC WAVES"
T. F. Tuan and D. T. Wang (Physics Department, University of Cincinnati, Cincinnati, Ohio 45221)

Hines has recently suggested that the equation for the velocity divergence rather than the equation for the pressure variable should be used in a "potential" approach to gravity waves on grounds that the "potential" for the velocity divergence equation used previously by Einaudi and Hines is well-behaved, while the "potential" for the pressure variable becomes singular whenever the gravity-wave frequency equals the local background Brunt frequency.

We have found that aside from the usual advantages of the pressure variable over the velocity divergence, both the pressure and the horizontal velocity exhibit interesting and unusual behavior at altitudes where the wave frequency equals the Brunt frequency. The singularity, therefore, cannot be considered as "spurious" as Hines suggests, since it can produce physical results that well-behaved "potentials" cannot. We have also verified that our results are consistent with the Hines' results for the velocity divergence. The latter does not show anything interesting at precisely the altitudes where the pressure and horizontal velocity exhibit their exceptional behavior. All the solutions have been verified to satisfy the basic coupled first order hydrodynamic equations.

J. Geophys. Res., A, Paper 4A0269

0499 General (Submillimeter Emission)
ATLAS OF STRATOSPHERIC SUBMILLIMETER LINES–I: THE 7–20 CM^{-1} INTERVAL
M. G. Baldecchi (Istituto di Ricerca sulle Onde Elettromagnetiche del CNR, Via Panciatichi 64, 50127 Firenze, Italy), A. Bonetti, B. Carli, M. Carlotti, F. Mencaraglia

The stratospheric emission in the submillimeter spectral region has been measured from

Electromagnetics

Exploration Geophysics

Geomagnetism and Paleomagnetism

Geodesy and Gravity

Hydrology

Meteorology

Journal of Geophysical Research

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to the time average stationary wave distribution. Applications to blocking are also considered. Interference of stationary and quasi-stationary modes can apparently produce regional as well as global blocking patterns. (Transient, stationary planetary waves).
J. Geophys. Res., D, Paper 4D0467

3750 H_2O in the Atmosphere (Fog)
CHEMICAL COMPOSITION OF RADIATION FOG WATER AT ALBANY, NEW YORK, AND ITS RELATIONSHIP TO FOG MICROPHYSICS
S. Fuzzi, R.A. Castillo (State University of New York at Albany, Atmospheric Sciences Research Center, ES324, 1400 Washington Avenue, Albany, New York 12222), J.E. Jiusto and G.G. Lala

Radiation fog water samples collected at the Albany (NY) County Airport show quite low acid content compared with previously published data on fog acidity: the pH ranges from 4.3 to 6.4. This fog water ionic concentration is indicative of low pollution in this area. The loading mechanism responsible for the variability in aqueous concentration of non-volatile ionic constituents of these fogs is the growth and evaporation of droplets, as reflected by the variation of LWC during the fog evolution. For this reason the origin and composition of aerosol on which fog droplet condensation takes place is of major importance. Droplet size spectra analysis show that there is a need for improving the collection methods of fog water, in order to better describe the chemistry involved, especially to maximize the drop capture efficiency of the collectors and reduce the sampling time for better resolution. (Acid fog, fog microphysics, fog chemical composition).
J. Geophys. Res., D, Paper 4D0512

3750 Precipitation (Chemistry)
SPATIAL VARIATION IN BULK PRECIPITATION CHEMISTRY AND IMPLICATIONS FOR SAMPLING IN AN UPLAND CATCHMENT
B. Reynolds (Institute of Terrestrial Ecology, Bangor Research Station, Penrhos Road, Bangor, Gwynedd, North Wales, U.K.)

Bulk precipitation was collected weekly for chemical analysis over a period of sixty four weeks at six sites within the headwater catchments of the Upper Wye in Mid-Wales, U.K. Results indicate that for these catchments, which are remote and uninhabited, the aspect and elevation of the collectors have no detectable effect on solute concentrations measured in bulk precipitation. Differences in rainfall catch within the watersheds contributed to the variation in solute loads to the sites. (Precipitation chemistry, sampling).
Water Resour. Res., Paper 4W0281

3735 Electrical Phenomena
THREE UNUSUAL STROKES IN A TRIGGERED LIGHTNING FLASH
V.P. Idone and R.E. Orville (Department of Atmospheric Science, State University of New York at Albany, Albany, New York 12222)

Time-resolved photographic records of three strokes of a triggered lightning flash are examined. These strokes exhibit several examples of novel behavior that include (1) the abrupt transformation of dart leaders to stopped leaders and (2) the partial "reflection" of dart leader luminosity back up the channel. Both phenomena are associated with an apparent discontinuity in channel characteristics between the natural and artificial (wire) sections of the channel. We estimate the ratio of characteristic impedances for these sections to have an upper bound of about a factor of three. Analysis of one of the dart leader "reflections" yields a propagation speed of 9.6×10^7 m/s, whereas the dart leader and return stroke speeds (2-D) over the same channel section are 1.7×10^7 m/s and 13×10^7 m/s, respectively. Also, one of the return strokes reveals the occurrence of two distinct waves of luminosity that are separated by only 5 μsec and that travel up nearly identical channels that differ only in the channel terminus.
J. Geophys. Res., D, Paper 4D0455

3749 General (Meteorology)
HIGH RESOLUTION FREQUENCY ANALYSIS OF GEOLOGICAL TIME SERIES
M. N. Siddiqui (Department of Statistics, Colorado State University, Fort Collins, Colorado 80523), and Chien-Chun Wang

A technique of high resolution frequency analysis is developed which meets the demands of resolving the characteristic frequencies of an almost periodic process. Furthermore, it has the property of statistical consistency so that as the sample size increases the estimates converge to the true frequencies. This technique is applied to three geological time series and it is shown that their characteristic frequencies are identical with some of the frequencies of the earth's orbital elements, or of their linear combinations. The analysis supports the Milankovitch orbital theory of long term climatic changes. (Frequency resolution, orbital elements, geological time series).
J. Geophys. Res., D, Paper 4D0469

Mineralogy, Petrology, and Crystal Chemistry

4210 Crystal chemistry
KIMBERLITIC CHLORITES FROM SIERRA LEONE, WEST AFRICA: CRYSTAL CHEMISTRIES AND STRUCTURAL POLYTYPES.
Linda A. Tompkins (Geology Department, University of Massachusetts, Amherst, Mass. 01003), S.W. Bailey and Stephen E. Haggerty.

Chlorites occur as ovoid discrete nodules (1-4cm), as anhedral macrocrysts (0.20mm) and euhedral crystals (0.05mm) in kimberlite, and as cleavage replacement products of high Fe (reversely pleochroic), low Ti + Cr phlogopites. The nodules are severely deformed and four textural groups are recognized (fibrous, platy, tectonized, multiple cleavage) that consist of intergrown chlorites and vermiculites of variable compositions. Major chemical types in the nodules are classified as high Fe (25wt%), intermediate Fe (15wt%), and low Fe (8wt%) varieties with a subgroup consisting of low Fe and high K (0.8-2.3 wt% K_2O). The chlorites have high SiO_2 (46.6 wt% max) and MgO (28 wt% max), and low Al_2O_3 (8-12 wt%) contents. High Fe^{3+} and later alteration result in vacancies (corroborated by electron densities) in the interlayer sheet. The chlorites and vermiculites are dominantly of the rare Ia structural type, intergrown with more typical IIb chlorite in some specimens. Two-layer "s" and "t" stacking sequences identified in Ia chlorites and vermiculites suggest alteration from parent 1M and $2M_1$ phlogopites, respectively. Chloritization of peridotitic phlogopite nodules and macrocrysts took place at relatively low P-T conditions concurrent with, or followed by crystallization of primary magmatic chlorite in the kimberlite groundmass.
Am. Min., 69, 3-4

4210 crystal chemistry
AN ATTEMPT TO SIMULATE HIGH PRESSURE STRUCTURES OF MG-SILICATES BY AN ENERGY MINIMIZATION METHOD
M. Miyamoto (Department of Pure and Applied Sciences, College of General Education, University of Tokyo, Komaba, Tokyo 153, Japan) and H. Takeda

A computer program (WMIN; Busing, 1981) that refines unknown repulsive parameters of ions or structural parameters of a crystal by minimizing the potential energy has been applied to simulating the crystal structures of high pressure minerals. We assumed Born-Mayer type repulsive forces. The repulsive parameters, ionic radius A, and ionic compressibility

B for Mg^{2+}, Si^{4+}, and O^{2-} ions obtained from structural data of α-Mg_2SiO_4 (forsterite), have been

applied to simulating the crystal structures of β-Mg_2SiO_4, γ-Mg_2SiO_4, hypothetical Mg_2SiO_4 with

Sr_2PbO_4 and $CaFe_2O_4$ structures, and $MgSiO_3$ with

perovskite and ilmenite structures. The results are compared with the observed structures refined by the X-ray diffraction data. We also predict the crystal structures of the minerals in situ at high pressure under the constraint that the cell dimensions are fixed at the observed values at high pressure. Our approach appears to be successful in constructing the 'framework' of relatively complex crystal structures of high pressure minerals and simulating the mode of crystal structure changes with increasing pressure. (crystal structure, high pressure, silicate, potential energy).
Am. Min., 69, 7-8

4210 Crystal Chemistry
TITANIUM AND THE COLOR OF STAUROLITE
C.M. Ward (Geology Department, University of Otago, Dunedin, New Zealand)

The visually assessed color intensity of staurolite appears to be directly proportional to the titanium content. It is inferred that the color is caused by absorption due to Fe^{2+} - Ti^{4+} charge transfer. From this and the pleochroic scheme it is further inferred that the titanium in staurolite is located in the tetrahedrally coordinated Fe site. The marked difference in Ti content of the various sectors in sector-zoned staurolite can be rationalized more satisfactorily with Ti in this site than in the alternative octahedral Al site. (Staurolite, titanium, tetrahedral coordination, sector-zoning).
Am. Min., 69, 3-4

4210 Crystal chemistry
THE CRYSTAL STRUCTURE OF HIGH CLINOFERROSILITE
S. Sueno (Department of Geoscience, University of Tsukuba, Ibaraki, 305 Japan), M. Kimata, and C. T. Prewitt

The crystal structure of high clinoferrosilite ($FeSiO_3$) with $C2/c$ symmetry after the transition from orthoferrosilite at 1025°C was determined at 1050°C using a high-temperature four-circle diffractometer. The cell constants are a=9.928(1)Å, b=9.179(1)Å, c=5.338(1)Å, =110.20°(1), V=456.5(1)Å³. The Fe2 polyhedron can be considered as six coordinated because the next two oxygens are too distant (3.191Å) for effective coordination with the Fe2 ion. The mean Si-O bond length is 1.634Å and the mean Fe-O bond lengths in the M1(6) and M2(6) polyhedra are 2.176Å and 2.300Å, respectively. The polyhedral volume calculation reveals that the six-coordinated M1 polyhedron (13.40Å³) is larger than the six-coordinated M2 polyhedron (11.93Å³). This is related to the large distortion of the Fe2-polyhedron in the high clinoferrosilite structure. A similar tendency was observed for the high-clinopyroxene structures reported previously. (Transition, high temperature).
Am. Min., 69, 3-4

4220 Descriptive Mineralogy
GAMAGARITE: A RE-EXAMINATION AND COMPARISON WITH BRACKEBUSCHITE-LIKE MINERALS
U.E. Harlow (Department of Mineral Sciences, American Museum of Natural History, New York, NY 10024), P.J. Dunn and G.R. Rossman

Gamagarite from Postmasburg district, Cape Province, Republic of South Africa, is re-examined using analytical chemical, infrared spectra, and X-ray diffraction techniques. The data indicate that gamagarite is isostructural with brackebuschite; space group is $P2_1/m$ (assumed center of symmetry) with unit cell constants a=9.15(1), b=6.17(1), c=7.68(1)Å, β =112.7(2)°. Infrared spectra indicate that strongly hydrogen-bonded OH^- is the dominant hydrogen-bearing species in both gamagarite and brackebuschite. Consequently, with a reevaluation of previously published structure data, our interpretation prefers the brackebuschite-type structure as a partially acid vanadate (arsenate and phosphate) containing HVO_4^{2-}-type units rather than as a hydrated vanadate containing structural water, as previously described. However, there are uncertainties with the assignment of Mn oxidation state. (Gamagarite, brackebuschite, IR Spectra, unit cell data).
Am. Min., 69, 7-8

4230 (Descriptive Mineralogy)
THE MINERALOGY AND PETROLOGY OF COMPOSITIONALLY ZONED ASH-FLOW TUFFS, AND RELATED SILICIC VOLCANIC ROCKS, FROM THE McDERMITT CALDERA COMPLEX NEVADA-OREGON
W. K. Conrad (Dept. Earth Sciences, Monash Univ., Clayton, Victoria, Australia 3168).

The McDermitt caldera complex, Nevada-Oregon, is a composite collapse structure formed following eruption of three ash-flow tuffs from a single compositionally zoned magma chamber. The major and early-erupted portions of the tuffs are mildly peralkaline high-silica comendite. Later erupted portions of two ash-flow sheets are metaluminous low-silica rhyolite. Associated with the caldera complex are precaldera dacite to rhyolite lava flows and postcaldera rhyolite domes and intrusives. Systematic variations in mineral compositions and whole-rock chemistry throughout the entire silicic volcanic suite record the petrogenesis of highly silicic comendite through fractional crystallization of dacitic or rhyodacitic parental magma. Fractionation from dacite-rhyodacite to metaluminous rhyolite is controlled by removal of plagioclase, low- and high-Ca pyroxenes and significant (5%) amounts of apatite, magnetite and ilmenite. Fractionation from rhyodacite-low-silica rhyolite to high-silica comendite is controlled by removal of ternary-alkali feldspar, quartz, ferroaugite-ferrohedenbergite, fayalite and lesser ilmenite, magnetite and apatite. HREE enrichment from dacite to rhyolite is pronounced in ash-flow tuffs and postcaldera volcanic rocks but not in precaldera lavas; this is possibly due to the variable presence of F as an HREE complexing agent during crystal fractionation in the caldera magma chamber. Fe-Ti oxide compositions and phase equilibria indicate progressively decreasing magmatic temperature and oxygen fugacity: 865-940°C in dacite-low-silica rhyolite, with f_{O_2} below the FMQ buffer, and approximately 800°C in high-silica comendite with f_{O_2} slightly above the WM buffer. In the ash-flow tuffs, observed patterns of vertical compositional zonation and phenocryst distributions reveal pre-eruptive processes important for the genesis of mildly peralkaline silicic magmas. Influx of heat is required to maintain crystallization of relatively mafic, high temperature mineral assemblages, notably with ternary feldspar, and prohibit further crystallization of derivative melts. Heat transfer occurred throughout a density-stratified magma chamber via convection within compositionally discreet zones of low- and high-silica rhyolite. (McDermitt, Nevada-Oregon; ash-flow tuffs).
J. Geophys. Res., B, Paper 4B0440

4260 Paragenesis, petrography, and petrogenesis
COEXISTING PARAGONITE AND QUARTZ IN SILLIMANITIC ROCKS FROM NEW MEXICO
Jeffrey A. Grambling (Department of Geology, University of New Mexico, Albuquerque, NM 87131)

Paragonite has been identified by electron microprobe and X-ray diffraction analysis in four specimens of metamorphic rock from northern New Mexico. The sodic mica coexists with quartz in three of these rocks. One comes from an area where kyanite, andalusite and sillimanite coexist. The other two come from widely separated areas where sillimanite is the only polymorph of Al_2SiO_5 to be found, and sillimanite coexists with paragonite and quartz in each. The paragonite-quartz-sillimanite assemblages appear to be stable. These are the first reported occurrences of this assemblage and its presence supports the Al_2SiO_5 triple point of Holdaway (1971).

Muscovite occurs in two of the paragonite-sillimanite quartzites. Because these two samples crystallized at similar temperatures, and define a solvus, K/(K+Na) ratios should be similar for the two muscovites and for the two paragonites. However, large differences in K/(K+Na) of muscovite exist between the two samples and smaller but significant differences in that ratio occur between the two paragonites. These variations may be related to differences in celadonite content of the muscovite in the two rocks. Consistent with tentative suggestions of previous workers, data presented here suggest that, as Fe and Mg are added to muscovite-paragonite pairs, K/(K+Na) increases in muscovite and decreases in paragonite. This relationship has serious implications for muscovite-paragonite solvus geothermometry since most natural muscovites and paragonites have small amounts of Fe and Mg. (Paragonite, kyanite, andalusite, sillimanite).
Am. Min., 69, 1-2

4260 Petrogenesis (Hawaiian Tholeiite)
ORIGIN OF HAWAIIAN THOLEIITE: A METASOMATIC MODEL
T. L. Wright (U. S. Geological Survey, Reston, Virginia 22092)

Hawaiian Tholeiite is generated by shear melting at the boundary between lithosphere and asthenosphere in a mantle which has already been melted to yield mid-ocean ridge tholeiite and been subsequently metasomatized. The metasomatic assemblage consists of a nepheline-normative fluid and amphibole precipitated from that fluid. Metasomatic constituents originate in the low-velocity zone and move upward in response to a thermal plume. Melting and eruption of Hawaiian Tholeiite are separated by a period of shallow storage not exceeding a few decades. Primary Hawaiian magmas have 20-22% MgO. Olivine is lost during upward transport and again during storage such that the average MgO content of stored magma is 13-14% and erupted magma is 9-10%. Secular chemical variation seen at Kilauea is ascribed to varying degrees of partial melting and metasomatic enrichment.
J. Geophys. Res., B, Paper 3B1513

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J. Geophys. Res., B, Paper 3B1513

4270 Properties of Minerals
THE HEAT OF FUSION OF FAYALITE
J.F. Stebbins (Earth Sciences Division, Lawrence Berkeley Laboratory, Berkeley CA 94720), I.S.E Carmichael

The relative enthalpies (H_T-H_{300K}) of crystalline fayalite (Fe_2SiO_4) and of the liquid resulting from the melting of fayalite in platinum and iron-plated capsules have been measured from 985 to 1705K by drop calorimetry. Analyses of the samples quenched from the liquid show that because of incongruent melting and disproportionation of FeO during cooling, a mixture of phases was produced, possibly including the mineral laihunite (~$Fe_2(SiO_4)_2$). Measured enthalpies have been corrected for these effects, resulting in an enthalpy of equilibrium, incongruent melting at 1490K of 88.4±1.1 kJ/mol and an enthalpy of hypothetical congruent melting of 89.3±1.1 kJ/mol. (heat capacity, enthalpy, melting).
Am. Min., 69, 3-4

4270 Properties of Minerals
MIXING PROPERTIES OF ALUMINOSILICATE GARNETS, AND APPLICATIONS TO GEOTHERMO-BAROMETRY
Ganguly, Jibamitra, Department of Geosciences, University of Arizona, Tucson, Arizona 85721; and Saxena, S.K., Department of Geology, Brooklyn College Brooklyn, New York 11210

The binary mixing properties and quaternary a-X relations in the (Fe,Mg,Ca,Mn)-garnets have been derived from thermodynamic and statistical analyses of the compositional properties of garnets and coexisting phases in natural and synthetic assemblages, and Wohl's (1953) multi-component subregular formulation. The garnet-biotite K_D-geothermometer of Ferry and Spear (1972) has been corrected for the compositional effects on the basis of these results. The estimated pressures of a large number of natural Gt-Plag-Al_2SiO_5(AS)-Q (GPAQ) assemblages (spanning a temperature range of 550-900°C) according to a $_{Grose}$ obtained in this work and a $_{An}$ derived by Saxena and Ribbe (1972) are in perfect agreement with the AS phase diagram of Holdaway. Furthermore, simultaneous calculations of P and T for the GPAQ+biotite assemblages described by Hodges and Spear (1982, Am. Mineral.) from New Hampshire yield conditions very close to the AS triple point, in conformity with their conclusion based on the spatial distribution of AS polymorphs. A summary of the binary Margules and ternary interaction parameters (C) are as follows (Cal/mole of cation). Ca-Fe join: W_H(Ca)=-630 (±400), W_H(Fe)=4620 (±660), W_S=1.5 e.u.; Fe-Mg: W_H(Fe) = 200, W_H(Mg)=2500 (±500); W_S=0; Mg-Mn: W_G = W_H=3000 (±500); Ca-Mg: Haselton and Newton (1980, JGR); Other binaries: Ganguly and Kennedy (1974, CMP); C_{123}=-5300, C_{124}=-1523, C_{134}=2625, C_{234}=-1150 with 1=Ca, 2=Mg, 3=Fe, 4=Mn; $C^{**}(i-j) = W_G^{ij}X_j + W_G^{ji}X_i)X_iX_j$.
Am. Min., 69, 1-2

4290 Instruments (Refractometer)
THE JEWELER'S REFRACTOMETER AS A MINERALOGICAL TOOL
C. S. Hurlbut, Jr. (Department of Geological Sciences, Harvard University, Cambridge, Massachusetts, 02138)

The jeweler's refractometer offers a simple method of determining the refractive indices of any mineral having a single polished surface of at least 1 mm² to a precision of about 0.002. For some crystallographic orientations of the polished surface of anisotropic crystals, it is necessary to determine the angles the vibration directions of the measured refractive indices make with the polished surface. This is accomplished by viewing the refractometer scale through a rotatable polarizing filter on which the transmission direction is indicated. With the knowledge of these angles, it is possible to tell if a crystal is uniaxial or biaxial; in uniaxial crystals to distinguish ω from ε and tell the optic sign, and in biaxial crystals to identify all three refractive indices and thus determine the optic sign. Similar measurements can be made on a single mineral grain in a polished thin section. (Refractometer, refractive index).
Am. Min., 69, 3-4

4299 Mineralogy, Petrology and Crystal Chemistry
LINDEMANN MELTING LAW: ANHARMONIC CORRECTION AND TEST OF ITS VALIDITY FOR MINERALS
G. H. Wolf (Geology Department, University of California, Berkeley, California, 94720), R. Jeanloz

High-pressure experimental data are used to evaluate the validity of the Lindemann melting criterion for minerals. Because anharmonicity can be significant at the high temperatures associated with melting, leading order anharmonic contributions to the mean-square atomic vibrations have been included in the present lattice dynamic formulation of the Lindemann criterion. The parameters required in this Lindemann expression can be determined from an inversion of thermodynamic data so that a direct comparison with experimental melting data can be made without resort to model potentials. In general, we find that although atomic vibrations can be significantly anharmonic near the melting point, the shape of the melting curve predicted from the Lindemann criterion is not much influenced by anharmonicity. We demonstrate that the Lindemann expression is inconsistent with experimental melting data for a variety of substances, particularly at low pressures. In some cases (argon, sodium chloride and potassium chloride), the melting slopes observed at high pressures are consistent with a Lindemann expression. In general, we find that a Lindemann criterion is not an adequate description of the melting behavior of minerals. Therefore, an application of the Lindemann law to obtain the melting temperatures of minerals at high pressures, and to determine the fusion curve of the earth's deep interior is, at present, speculative. (Lindemann, Melting Anharmonic).
J. Geophys. Res., B, Paper 4B0437

Oceanography

4705 Boundary layer and exchange processes
THE VARIATION OF SEA SURFACE TEMPERATURE IN 1976 AND 1977 PART II: THE SIMULATION WITH MIXED LAYER MODELS
K. Miyakoda and A. Rosati, (Geophysical Fluid Dynamics Laboratory/NOAA, Princeton University, Princeton, New Jersey 08542)

In connection with a study of the extreme weather events over the North American Continent in January, 1977, analyses were performed to investigate characteristic properties of spatial and temporal variation of sea surface temperature (SST) for the years of 1976 and 1977, using world distribution of SST described in the accompanying paper, Part I. The time evolution of ocean temperature patterns for these years are displayed by latitudinal distribution diagrams of SST, and longitude-time (Hovmöller) diagrams. Gill-Turner's integral model and Mellor-Durbin's turbulence closure model of the mixed layer were applied to calculate the SST anomaly in the Northern Hemisphere, using realistic atmospheric forcing. Increase of time variability of the external forcing leads to an appreciably improved simulation of the SST anomaly fields. Both models gave reasonable external predictions for about 5 months in winter time, if the realistic external forcings were specified. (SST simulation, mixed layer models).
J. Geophys. Res., C, Paper 4C0458

4710 Chemical oceanography
ANALYSIS OF A RELATIONSHIP BETWEEN THE VERTICAL DISTRIBUTION OF INORGANIC CARBON AND BIOLOGICAL PRODUCTIVITY IN THE OCEANS
J. A. Viecelli, Lawrence Livermore National Laboratory, Livermore, California 94550

If the assumption of steady state is made then over large temporal and spatial scales a balance between the downward flux and oxidation of organic detritus and upward mixing of inorganic carbon determines the vertical distribution of inorganic carbon in the ocean. From a mathematical statement of this balance using an empirical formula for the downward organic flux determined by Suess [1980] I derive an expression for the vertical inorganic carbon profile containing one parameter C_p/k, the ratio of primary productivity measured by the ^{14}C inculation method to the effective vertical eddy mixing coefficient. The best estimate for this ratio obtained by minimizing the variance between the available inorganic carbon concentration data and the derived curve is 1.5×10^{-3} mol C m^{-4}. This ratio is consistent with average primary productivities in the range of 100 to 170 g C m^{-2} yr^{-1} if one uses recent k value estimates based on radiocarbon and tritium measurements [Broecker et al., 1980; Stuiver, 1980; Stuiver and Quay, 1983], and is equivalent to 20 to 34 gCm^{-2} yr^{-1} of new production using the definition of Eppley and Peterson [1979].
Work performed under the auspices of the U. S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.
J. Geophys. Res., C, Paper 4C0484

4720 Distributions & Water Masses
MASS TRANSFER BETWEEN GULF STREAM RINGS
R. P. Mied and G. J. Lindemann (Marine Technology Division, Naval Research Laboratory, Washington, D.C., 20375)

Experiments are performed to examine the close interaction of two anticyclonic Gulf Stream rings. A tracer is put in one ring initially, is advected, and diffuses into the other as the pair evolve in time. The appearance of the tracer streaklines is examined in the light of conservation of potential vorticity. Kinematic viscosity and tracer diffusivity are each varied over two orders of magnitude, and tracer behavior changes greatly. The analogy of this work to the interaction of a warm core ring with the Gulf Stream is made, with the streamers observed in this work corresponding to those observed in ring/Stream interactions.
J. Geophys. Res., C, Paper 4C0376

4765 Surface Waves
ESTIMATES OF THE JOINT STATISTICS OF AMPLITUDES AND PERIODS OF OCEAN WAVES USING AN INTEGRAL TRANSFORM TECHNIQUE
K.T.Shum and W.K.Melville (R.M.Parsons Laboratory, Massachusetts Institute of Technology, Cambridge, MA 02139)

An integral transform (the Hilbert Transform) method is used to obtain continuous time series of wave amplitude and period from ocean wave measurements. The joint statistics of these two variables are determined and directly compared with the theoretical probability densities predicted by Longuet-Higgins (1975, 1983). Good agreement is found for data from both calm and hurricane sea states over a broad range of bandwidths. This method avoids the ambiguities in the definitions of wave amplitude and period found in earlier comparisons of field data with theory. (Wave statistics)
J. Geophys. Res., C, Paper 4C0295

4770 Turbulence and diffusion
FORMATION OF THERMOCLINES IN ZERO-MEAN-SHEAR TURBULENCE
Rory O.R.Y. Thompson (CSIRO Division of Oceanography, G.P.O. Box 1538, Hobart, Tasmania, Australia, 7001).

Heating Q at the surface of a turbulent and, initially, unstratified ocean may form a thermocline, if strong enough. It is proposed here that the heating is strong enough if turbulence occurs sufficiently rarely past some depth not to transport heat downward. Turbulence is taken not to occur if the gradient Richardson number $Ri = N^2/u_z^2 + v_z^2$) rises above a critical value of 1/4. The probability that this occurs becomes very small when and where the population Richardson number $\bar{Ri} = \bar{N^2}/(\bar{u_z^2} + \bar{v_z^2})$ is greater than about 4/3. This traps the heat above that layer, increasing Ri and forming a thermocline. Let stirring action F be generated at a depth D below heating, and scale the heating as $B = gαQ/ρc_p$. Then the population Richardson number criterion translates to: if $H = BD^4/F^3 < H_c = 1.6$, a thermocline will form above the stirring ("tidal friction"). If $H < H_c$, no thermocline will form above the stirring, but after a time $0.9(K/B)^{\frac{1}{2}}$, the thermocline will form at a depth $0.6D + 2.2(K^3/B)^{\frac{1}{4}}$ below the stirring ("wave breaking"). These theoretical results match experimental results of *Kopfinger & Linden (1983)*.
J. Geophys. Res., C, Paper 4C0545

Particles and Fields— Interplanetary Space

5340 Shock Waves
SUPRATHERMAL IONS UPSTREAM FROM INTERPLANETARY SHOCKS
J. T. Gosling (University of California, Los Alamos National Laboratory 87545), S. J. Bame, W. C. Feldman, G. Paschmann, N. Sckopke, and C. T. Russell

Suprathermal ions with energies between solar wind thermal energies and 29 keV are occasionally observed ahead of outward propagating interplanetary shocks with the Los Alamos/Garching fast plasma experiment on ISEE-1 and -2. Compared to suprathermal ion velocity distributions observed upstream from the earth's bow shock, the upstream interplanetary shock ion velocity distributions are relatively structureless, and the particle fluxes are less intense. Typically the suprathermal ion distribution emerges smoothly from the solar wind thermal distribution and is nearly isotropic in the solar wind frame. Such distributions are observed with the fast plasma experiment only in association with interplanetary shocks. Field-aligned beams, kidney bean-shaped distributions, shells of ions in velocity space, and bunches of gyrating ions--all common to the upstream region of the earth's bow shock--have not been observed ahead of interplanetary shocks. Highly structured ion velocity distributions observed upstream of the earth's bow shock apparently are caused directly or indirectly by the nearly specular reflection of solar wind ions at the shock, a consequence of the generally high Mach number of the solar wind flow at 1 AU. By way of contrast, most interplanetary shocks at 1 AU have low, subcritical Mach numbers, and solar wind ion reflection at these shocks does not appear to play a role in producing upstream suprathermal ion distributions at 1 AU. Nevertheless, solar wind ions are accelerated to high energies at interplanetary shocks. Leakage of shocked thermal plasma across these low Mach number shocks from the downstream region may play an important role in producing upstream suprathermal ion populations and may therefore constitute the first step in the acceleration of solar wind ions to high energies at these shocks. (Shocks, ion acceleration).
J. Geophys. Res., A, Paper 4A0489

5340 Particles and Fields - Interplanetary Space (shock waves)
PLASMA AND ENERGETIC PARTICLE STRUCTURE UPSTREAM OF A QUASI-PARALLEL INTERPLANETARY SHOCK
C. F. Kennel et al. (TRW Space and Technology Group, Bldg. R1, Room 1176, One Space Park, Redondo Beach, California, 90278)

This paper assembles ISEE-1, -2, and -3 observations of the interplanetary magnetic and electric fields, plasma, magnetohydrodynamic waves, electromagnetic and electrostatic plasma waves, 1 to 6 keV protons and electrons, and ~30 keV/Q ions for the interplanetary shock of November 12, 1978. The shock was high-speed (640 km-s⁻¹), supercritical, quasi-parallel, and an efficient accelerator of energetic protons. The flux of >35 keV protons increased by a factor 15 in the last 45 min and 270 R_E before shock encounter. The >30 keV proton energy density approached that of the magnetic field and thermal plasma upstream of the shock. The shock was inside a closed magnetic structure, that was connected at both ends to the shock. The intensity of ion acoustic and low-frequency MHD waves increased inside the closed magnetic bubble. (Upstream waves, upstream particles, interplanetary shocks.)
J. Geophys. Res., A, Paper 4A0443

5340 Particles and Fields - Interplanetary Space (shock waves)
STRUCTURE OF THE NOVEMBER 12, 1978 QUASI-PARALLEL INTERPLANETARY SHOCK
C. F. Kennel et al. (TRW Space and Technology Group, Bldg. R1, Room 1176, One Space Park, Redondo Beach, California, 90278)

An objective of this paper is to determine the jump in plasma parameters across the November 12, 1978 interplanetary shock, sufficiently accurately to test in a subsequent paper a major prediction of shock acceleration theory-the dependence of the energetic ion spectral index upon the density compression ratio. We use ISEE-1 and -3 measurements of the magnetic field and electron and proton densities, temperatures, and bulk velocities, as well as ISEE-3 alpha particle measurements, and confirm the ISEE-1 electron densities using plasma wave measurements. We solve for the shock normal using four independent methods, and show that the upstream and downstream flow parameters are consistent to better than 10% with γ=5/3 Rankine-Hugoniot jump conditions. We conclude that the November 12, 1978 shock was a high speed (612km-s⁻¹), supercritical, quasi-parallel ($θ_{Bn}$=41°) shock of moderate strength (fast Mach number of 2.8) propagating into an upstream plasma whose total β was 1.14, and whose electron-to-proton temperature ratio was 2.8. This shock had three dissipative scalelengths, one of a few Larmor radii associated with its magnetic field jump, one of about 10 R_E associated with electron equilibration, and one of about 30 R_E associated with an energetic proton foreshock.
J. Geophys. Res., A, Paper 4A0442

5380 Solar Wind Plasma
A RE-EXAMINATION OF ROTATIONAL AND TANGENTIAL DISCONTINUITIES IN THE SOLAR WIND
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ISEE-3 magnetic field and proton data are used to study the properties of rotational and tangential discontinuities in the solar wind. A Sonnerup-Cahill minimum variance analysis of the magnetic field data is used to determine the direction of the normal to each discontinuity. The discontinuities are then classified as rotational (RD), tangential (TD), or either (ED), depending on the relative values of the normal field component and the change of field magnitude across them. This process yields substantially more RDs than TDs, in agreement with earlier studies using this method of classification.

Other field and plasma parameters are then examined for each of these three groups. The field magnitude passes through a local minimum while the field direction is changing for some TDs, but not for RDs. The first and second adiabatic invariants for protons and the helium abundance are approximately conserved across RDs, but not across TDs, although the helium abundance is observed to change at a small fraction of the RDs. The product of plasma density times the anisotropy factor tends to be conserved across all three types. The relative directions of the velocity and field changes across all three types of discontinuity are consistent with the propagation of RDs outward from the Sun, even though no such relation is predicted for TDs. The magnitude of the velocity change at RDs is smaller than predicted by MHD theory, and the use of a two-stream fit to the proton data reduces, but does not remove this discrepancy. The speeds of the alpha particles and the secondary proton beam relative to the primary proton beam result in little interaction between the alphas and RDs, while the primary and secondary proton beams flow through RDs in opposite directions and have oppositely directed velocity changes.

The plasma conditions at EDs show a closer resemblance to RDs than to TDs. (Discontinuities).
J. Geophys. Res., A, Paper 4A0426

Particles and Fields— Ionosphere

5515 (Aurorae)
NIGHTTIME AURORAL ENERGY DEPOSITION IN THE MIDDLE ATMOSPHERE
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From 1976 through 1982, eight distinct nighttime auroral events have been probed with rocket payloads in a series of high latitude studies at Poker Flat Research Range, Alaska and Andøya, Norway. The instrument packages have contained x-ray and energetic electron detectors, permitting a measure of these energy forms and their absorption in the middle atmosphere. Although the specifics of each event show a wide range of values for energy flux and spectral hardness, certain general characteristics persist in all cases. The primary energy sources for the middle atmosphere under the active conditions examined here are mainly relativistic electrons and bremsstrahlung x-rays. Each of these sources is found to dominate ionization in a separate altitude region, with the electrons usually controlling ionization in the upper heights above 55-60 km and the x-rays below to about 40 km, where cosmic rays take over. The relativistic electron ionizing radiation source has not usually been considered in modeling studies for the ion chemistry of the lower mesosphere (55-70 km), yet this radiation is capable of increasing ion concentration and electrical conductivity in excess of a factor of ten. Moreover, the persistence of relativistic electrons as an important source in all events studied here strongly suggests that this deficiency be corrected. (Aurora, electron measurements, x-ray measurements, atmospheric ionization).
J. Geophys. Res., A, Paper 4A0493

5545 Ionospheric disturbances
HIGH-LATITUDE IRREGULARITIES IN THE LOWER F-REGION: INTENSITY AND SCALE SIZE DISTRIBUTIONS
P. Rodriguez and E. P. Szuszczewicz (E.O. Hulburt Center for Space Research) Naval Research Laboratory, Washington, DC 20375)

A wide range of lower F-region irregularity scale sizes (75 m - 150 km) at high northern latitudes during the spring and summer of 1978 has been studied. The morphology and intensity distribution of the irregularities suggest that particle precipitation is the primary source of the larger scale density fluctuations, with second-order effects (e.g., plasma instabilities) contributing to the smaller scale sizes. Under conditions of moderate geomagnetic activity (K_p ≈ 2-3, AE ≲ 100), the most intense density enhancements (≈ 10^6 cm^{-3}) occur in the auroral oval. Large (L > 7.5 km) and small scale (7.5 km > L > 75 m) irregularities are most prominent in the dayside auroral oval, including the region of the polar cusp. Density enhancements within the polar cap have been detected principally toward the duskward side. These polar cap enhancements are similar to auroral oval enhancements, suggesting that polar cap precipitation is the source. The altitude range (170 - 200 km) of the observations implies that chemical recombination is the primary decay mode of the irregularities. The decay rate of the irregularities is sufficiently fast that convection cannot transport the observed irregularities far from their source regions.
J. Geophys. Res., A, Paper 4A0529

5550 Low-latitude ionospheric currents
GEOMAGNETIC PERTURBATIONS AT LOW LATITUDES OBSERVED BY MAGSAT
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Geomagnetic perturbations (ΔH, ΔD, ΔZ, and ΔF) at low latitudes are studied by using MAGSAT data during the mission lifetime from November 1979 through May 1980, and the following characteristics are found: (1) ΔH generally shows negative values larger at dusk than at dawn, and it is in good correlation with the Dst index on both dawn and dusk sides. The difference between dusk side and dawn side shows good correlation with the AE index; (2) ΔD shows a distinct variation near the dip equator only on the dusk side, with a small shift of the base line; (3) ΔZ shows a general tendency of being positive in the northern hemisphere and negative in the southern hemisphere; (4) ΔF generally shows negative values larger at dusk than at dawn, and it changes sinusoidally with latitude. These characteristics are discussed in relation to ionospheric and magnetospheric currents. (Geomagnetic perturbations, electric current, MAGSAT).
J. Geophys. Res., A, Paper 4A0527

5563 Plasma Motion, Convection, or Circulation
QUASI-STEADY STATE MULTI-PLASMA CLOUD CONFIGURATIONS IN THE F-REGION IONOSPHERE
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The morphology of a finite array of plasma density enhancements (multi-plasma clouds) in the ionosphere is studied in order to determine the condition under which the system undergoes a quasi-steady state E x B drift. In such a system, the polarization induced self-electric field inside all the plasma clouds must be essentially equal and uniform. The method of image dipoles previously developed for multi-equatorial spread F bubbles is used to calculate the instantaneous electric field exactly. It is found that, even for small separation distances for which the inter-cloud interaction is significant, the electric field inside the clouds remains nearly uniform both internally and from cloud to cloud for typical ionospheric plasma cloud parameters so that the multiple plasma clouds drift in unison without changing their geometrical shapes. This constitutes a quasi-steady state configuration. The implications to the behavior of late-time plasma cloud striations are discussed.
J. Geophys. Res., A, Paper 4A0525

5590 Techniques (Ionospheric reflection)
THE RADIO POWER REFLECTED FROM ROUGH AND UNDULATING IONOSPHERIC SURFACES
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It is shown for both rough and undulating surfaces that the mean radio power reflected by the ionosphere averaged over a sufficiently long time is exactly the same as for a smooth flat surface at the same height provided the sounder is equally sensitive for echoes from all directions. When making radio wave absorption measurements under spread conditions the total integrated power over the whole time the direct echoes are being received must be used but the distance attenuation factor must be calculated from the time of arrival of the first echo.
Rad. Sci., Paper 4S0508

Particles and Fields— Magnetosphere

5736 Magnetic tail
ASSOCIATIONS OF GEOMAGNETIC ACTIVITY WITH PLASMA SHEET THINNING AND EXPANSION: A STATISTICAL STUDY
E. W. Hones (Los Alamos National Laboratory, Los Alamos, NM 87545), T. Pytte and H. I. West, Jr.

Associations of geomagnetic activity in the auroral zone with thinnings and expansions of the magnetotail plasma sheet are examined statistically in this report. We first identified many plasma sheet thinnings and expansions in plasma and particle data from Vela satellites and from Ogo 5 without reference to ground magnetic data. These events were grouped according to the location of the detecting satellite in the magnetotail. For each such group the times of thinning or expansion were then used as fiducial times in a superposed epoch analysis of the geomagnetic AL-index values that were recorded in eight-hour intervals centered on the event times. The results show that many plasma sheet thinnings and expansions are related to discrete negative bay structures that are the classical signature of substorms. Furthermore, they support earlier findings that plasma sheet thinning and expansion at the Vela orbit (r≈18 R_E) tend to be associated with, respectively, the onset of the auroral zone negative bay and the beginning of its subsidence. Earthward of r = 13-15 R_E plasma sheet expansion occurs near the time of the onset of the negative bay, again in agreement with earlier findings. A large fraction of plasma sheet expansions to half-thicknesses ≥ 6 R_E at the Vela orbit are not associated with a bay-like geomagnetic disturbance but with subsidence of a prolonged interval of disturbance. The study also shows that many plasma sheet expansions are related simply to generally enhanced geomagnetic activity showing no bay-like or other distinctive features. (Plasma sheet, geomagnetic activity).
J. Geophys. Res., A, Paper 4A0441

5736 Magnetic Tail
ELECTRON ENERGIZATION IN THE GEOMAGNETIC TAIL CURRENT SHEET
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Electron motion in the distant tail current sheet is evaluated and found to violate the guiding center approximation at energies ≳ 10 eV. Fast electrons within the energy range 10^{-1}-10^2 keV that enter the current sheet become trapped within the magnetic field-reversal region. These electrons then convect earthward and gain energy from the cross-tail electric field. If the energy spectra of electrons entering the current sheet is similar to that of electrons from the boundary layer surrounding the magnetotail, the energy gain from the electric field produces electron energy spectra comparable to those observed in the Earth's plasma sheet. Thus current sheet interactions can be a significant source of particles and energy for plasma sheet electrons as well as for plasma sheet ions. A small fraction of electrons within the current sheet have their pitch angles scattered so as to be ejected from the current sheet within the atmospheric loss cone. These electrons can account for the electron precipitation near the high-latitude boundary of energetic electrons, which is approximately isotropic in pitch angle up to at least several hundred keV. Current sheet interaction should cause approximately isotropic auroral precipitation up to several hundred keV energies, which extends to significantly lower latitudes for ions than for electrons in agreement with low-altitude satellite observations. Electron precipitation associated with diffuse aurora generally has a transition at 1-10 keV to anisotropic pitch angle distributions. Such electron precipitation cannot be explained by current sheet interactions, but it can be explained by pitch angle diffusion driven by plasma turbulence.
J. Geophys. Res., A, Paper 4A0494

5736 Magnetic tail
MICROSTRUCTURE OF MAGNETIC RECONNECTION IN EARTH'S MAGNETOTAIL
J. W. Bieber (Bartol Research Foundation, University of Delaware, Newark, Delaware 19716), E. C. Stone, E. W. Hones, Jr., D. N. Baker, S. J. Bame, and R. P. Lepping

A recent study of magnetic reconnection in Earth's magnetotail identified 5 events in which a pulse of heated electrons appeared near the end of an interval of fast tailward plasma flow. Further investigation of these events has revealed the following information on their microstructure:
(1) Measurements of the electron velocity distribution show that the temperature rise can be characterized as a true heating process, in that the gross evolution of the distribution is from a narrower to a broader Maxwellian.
(2) During the heating pulse, a bump is often apparent in the tail of the electron distribution function at an energy of 2-5 keV. This bump could be the remnant of a beam produced by a 2-5 kV parallel potential drop. Thus, a possible mechanism for the heating of electrons is the beam-plasma instability.
(3) The magnetic field during these events is highly variable in all three components. Part of this variability may result from magnetic turbulence generated by the tearing-mode instability, but minimum variance analysis suggests that some of the more rapid variations (up to 20 nT/s) are caused by rotational or tangential discontinuities.
(4) Both the Y and Z components of the magnetic field are quite large (10-20 nT) at times. The strongest southward fields are usually observed near the beginning of the heating pulse, while the strongest Y components generally occur during the pre-heating interval of tailward plasma flow. Transient large-scale changes in the normal magnetotail current system are indicated by these observations. (Magnetic reconnection, substorms, magnetotail, plasma sheet).
J. Geophys. Res., A, Paper 4A0486

5742 Magnetosheath
MAPPING THE MAGNETOSHEATH FIELD BETWEEN THE MAGNETOPAUSE AND THE BOW SHOCK: IMPLICATIONS FOR MAGNETOSPHERIC PARTICLE LEAKAGE
J. G. Luhmann (Institute of Geophysics and Planetary Physics, University of California, Los Angeles, California, 90024), R. J. Walker, C. T. Russell, J. R. Spreiter, S. S. Stahara and D. J. Williams

Observational studies have attributed some of the energetic (≳ 50 keV) particles observed at various sites near the bow shock and in the magnetosheath to a magnetospheric source. A large-scale picture of the spatial distribution of these particles in the magnetosheath is difficult to obtain from the data because of constantly changing interplanetary conditions. Here an approximate picture of the volumes occupied by particles that originate in the vicinity of the magnetopause is obtained by mapping magnetosheath magnetic field lines which drape over the magnetopause through the bow shock. Subsets of those field lines that connect to potential sites of magnetic merging on the magnetopause are also traced in the event that the particle leakage occurs preferentially where normal components of the field are present across that boundary. The results of this modeling exercise suggest that energetic magnetospheric particles which are not scattered by magnetosheath magnetic fluctuations are likely to exit the magnetosheath in the region of the quasi-parallel shock.
J. Geophys. Res., A, Paper 4A0516

5785 Magnetospheric configuration
COMPARISON OF INDUCED MAGNETOSPHERES AT VENUS AND TITAN
M. I. Verigin and K. I. Gringauz
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Considerable evidence exists from data obtained by artificial satellites of Venus describing the detached bow shock wave which develops due to the interaction of the super-Alfvenic, supersonic solar wind. However, there is no such direct evidence for any bow shock wave at Titan due to the interaction with the co-rotating Saturnian magnetosphere. This is because the fast mode MHD Mach number was less than unity at the time of Voyager 1 close fly-by. In spite of this difference in plasma regimes, there is a certain striking similarity in these two interactions. Both obstacles to plasma flow have appreciable ionospheres and are globally non-magnetic. Downstream from both obstacles, an induced bipolar magnetic tail is formed with a central field reversal region which is analogous to the Earth's neutral sheet-plasma sheet region. There appears to be evidence for magnetic merging in these induced tails so that magnetic reconnection between the oppositely directed tail lobes occurs. The single tail crossing at Titan shows evidence of merging while the repeated tail crossings at Venus indicate that similarly observed merging there is not a permanent feature.
J. Geophys. Res., A, Paper 4A0495

5760 Plasma motion, convection, or circulation
PLASMA IN SATURN'S MAGNETOSPHERE
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The spatial and compositional distributions of the thermal plasma in the magnetosphere of Saturn is described in the light of the Voyager encounters. Theoretical considerations are applied to the elucidation of the structure, including two external and two internal boundaries. The outer boundary is a magnetohydrodynamic entity while the inner boundary of locally created thermal plasma is a result of the dissociative recombination of corotating molecular ions. The internal boundaries which we have reason to conclude separate plasmas of different composition are explained as a charge exchange quasi-resonance phenomena.
J. Geophys. Res., A, Paper 4A0120

5760 Plasma motion, convection, or circulation
ADIABATIC THEORY IN RAPIDLY ROTATING MAGNETOSPHERES
Andrew F. Cheng (Johns Hopkins University, Applied Physics Laboratory, Laurel, Maryland, 20707)

The Jovian magnetosphere is a rapid rotator in the sense that the corotation velocity exceeds the gyrovelocity for most of the low energy plasma particles. Ordinarily an electric drift velocity greater than the gyrovelocity will destroy the near periodicity of the bounce motion, so the parallel invariant J will no longer be valid. However, this paper shows that J invariance actually remains valid in rapidly rotating magnetospheres, so long as departures from rigid rotation are not too great. Northrop and Birmingham have already proved J invariance for the case of rapid but exactly rigid rotation, and this paper extends their results to non-rigid, rapid rotation with corotation lag and/or convection. These results allow the magnetic field to be arbitrarily asymmetric. The guiding center equations in the rotating frame are also used to obtain conditions for plasma corotation in arbitrarily asymmetric but rigidly rotating magnetic fields. The plasma bulk velocity equals the corotation velocity for any trapped particle population which is steady state in the corotating frame, provided E + (Ω × r) × B/c = 0 and all first order drifts are negligible. These conditions are satisfied, and corotation is expected, for a steady state cold plasma on equipotential field lines of any geometry threading a rigidly rotating central conductor. (Adiabatic theory, parallel invariant, rotation).
J. Geophys. Res., A, Paper 4A0175

5770 Short period (less than 1 day) variations of magnetic field
SIMULTANEOUS OBSERVATIONS OF A PULSATION EVENT FROM THE GROUND, WITH BALLOONS AND WITH A GEOSTATIONARY SATELLITE ON AUGUST 12, 1978
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A pulsation event with a period of 6-8 min has been observed simultaneously by the geostationary satellite GEOS 2 and two balloons located in the area magnetically conjugate to the satellite. The balloons were equipped with electric field and X ray instruments. The pulsation event occurred in the magnetic local time sector 06 - 11 determined by ground based measurements. The satellite instruments observed the signature of a magnetosonic wave having a radially inward directed Poynting vector. The electric field associated with the wave was closely correlated with the electric field detected by the balloon instrument near the foot point of the magnetic field line through GEOS 2. The ground based observations show that the wave phase pattern was north-south striated and that it moved from east to west. The balloon X ray measurements showed a strongly pulsating particle precipitation, in close correlation with the intensity of the energetic electron flux and the VLF electromagnetic radiation measured on the satellite suggesting a wave-particle interaction process. The pulsations seem to originate beyond the geosynchronous orbit. The study demonstrates the usefulness of simultaneous measurements with a geostationary satellite and instruments in the ground area magnetically conjugate to the satellite.
J. Geophys. Res., A, Paper 4A0490

5770 Short-period (less than 1 day) variations of magnetic field
MULTISPACECRAFT OBSERVATIONS OF THE HARMONIC STRUCTURE OF Pc 3-4 MAGNETIC PULSATIONS
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Harmonically related Pc 3-4 pulsations (7-100 mHz) are observed simultaneously by the three geosynchronous satellites ATS 6, SMS 1, and SMS 2, which are separated 20° from one another. At a given instance the frequency of the same harmonic is different from one spacecraft to another and each spacecraft observes a decrease in the fundamental frequency as it moves from morning (15 mHz) to afternoon (10 mHz). This frequency behavior is explained in terms of standing Alfvén waves, for which the frequency is determined by the local magnetic field and plasma density. Occurrence of harmonic Pc 3-4 waves only during daytime hours (0400-2000 LT) and their frequency characteristics suggest a broadband energy source located on the day side. Possible azimuthal wave number m and azimuthal phase velocity $V_φ$ of the second through fourth harmonics are determined from an unusual interval during which identical harmonic frequencies were observed at SMS 1 and ATS 6. Under the assumption of tailward propagation of constant-phase fronts at the same velocity for all these harmonics, we obtain $V_φ$ ~ 1700 km/s. (Magnetic pulsations, harmonic waves, geosynchronous orbit).
J. Geophys. Res., A, Paper 4A0537

5770 Short period variations of magnetic field
LONGITUDINAL STRUCTURE IN PI 2 PULSATIONS AND THE SUBSTORM CURRENT WEDGE
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The characteristics of midlatitude Pi 2 pulsations are studied using a sub-auroral east-west chain of magnetometers which spans over four hours local magnetic time. The midlatitude magnetic bays associated with the Pi 2 pulsations are used to define a longitudinal coordinate system based on the substorm current wedge model. The wave properties, frequency, polarization and east-west phase variations, are examined in this coordinate system. This allows us to compare the wave characteristics at longitudes between the meridians of the two field-aligned currents of the substorm current wedge with the characteristics both east and west of these meridians. In an attempt to minimize the influence of preexisting current systems on our estimate of the substorm current location we use only Pi 2 pulsations which follow a magnetically quiet interval and which start simultaneously with a magnetic bay. We find that the longitudinal pattern of the horizontal polarization ellipse azimuth found earlier, extends beyond the meridians of the field-aligned currents. The sense of wave horizontal polarization is predominantly counterclockwise at all longitudes though the incidence of linear and clockwise polarization increases with distance from the field-aligned current meridians. Estimates of signal phase differences between station pairs, if interpreted as azimuthal phase propagation, show that westward propagation dominates west of and within the field-aligned current meridians, but that eastward propagation dominates east of the current system. This latter observation fits a recent model introduced to explain the longitudinal variation in polarization azimuth. We also looked for variations in the signal frequency among stations and found some variation in about half the events studied, but could find no systematic behavior.
J. Geophys. Res., A, Paper 4A0476

5799 General (Sputtering)
ESCAPE OF SULFUR AND OXYGEN FROM IO
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Charged particle sputtering is re-examined as a mechanism for escape of sulfur and oxygen from Io. Corotating ions and energetic ions are considered, using the best available determinations of ion fluxes and sputtering yields. It is unclear whether molecular SO_2 is the dominant escaping neutral from Io, or atomic O and S, but the Voyager detection of SO_2^+ in the cold torus implies the presence of molecular SO_2 there. Thin atmosphere models encounter serious difficulty in achieving adequate sulfur and oxygen escape rates, but they are not yet ruled out. Ionization and dissociation in a sputter corona make important contributions. In thick atmosphere models, the neutral escape rates can be much higher, but the oxygen escape rate tends to be too high relative to the sulfur escape rate unless diffusive separation in the atmosphere is limited, perhaps by rapid mixing. (Sputtering, oxygen and sulfur escape).
J. Geophys. Res., A, Paper 4A0452

Physical Properties of Rocks

6120 Equation of state
HUGONIOT DATA FOR PYRRHOTITE AND THE EARTH'S CORE
J.M. Brown (Geophysics Department, Texas A & M University, College Station, TX 77843), T J. Ahrens, and D L. Shampine

New shock-wave Hugoniot data for pyrrhotite ($Fe_{0.9}S$) now describe the equation-of-state to nearly two-fold compression at a maximum pressure of 274 GPa. A minor discontinuity on the Hugoniot between 100 and 150 GPa is interpreted as the melting transition. While not tightly constrained, the inferred melting point lies below lower-bound temperature estimates based on the Lindemann criterion. The highest pressure Hugoniot data (representing the melted phase) are used to model the equation-of-state for liquid iron-sulfide. A density for liquid pyrrhotite of 7.80 ± .10 Mg/m³ under core-mantle boundary conditions (P= 135 GPa, T= 4000 K), is calculated. Assuming that sulfur is the primary alloying element in a predominantly iron core, the present data are consistent with a homogeneous outer core containing 10 ± 4wt % sulfur. (Hugoniot, pyrrhotite, core, iron sulfide)
J. Geophys. Res., B, Paper 4B0358

6199 General (Permeability)
PERMEABILITY OF FAULT GOUGE UNDER CONFINING PRESSURE AND SHEAR STRESS
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The permeability of both clay-rich and non-clay gouges, as well as several pure clays, was studied as a function of confining pressures from 5 to 200 MPa and shear strain to 10. Permeability ranged over four orders of magnitude, from around 10^{-22} to 10^{-18} m² (1 darcy = .987 × 10^{-12} m²). The lowest values were characteristic of the montmorillonite-rich and finer grained non-clay gouges. Illite, kaolinite and chlorite had intermediate permeabilities, while the highest values were typical of the serpentine and coarser grained non-clay gouges. Grain size was an important factor in determining permeability, particularly for the clay-rich samples. The coarse grained gouges were the most permeable and decreased in permeability after shearing. Conversely, the fine grained gouges had characteristically lower permeabilities that did not vary significantly after various amounts of shearing. The permeabilities of the non-clay samples were not significantly different than those of the clays. Therefore, comminuted rock flours can be equally as effective in reducing the flow of water as the characteristically low permeability clay gouges.

The strengths of the samples were quite variable. The non-clay gouges were consistently the strongest with yield points (beginning of non-elastic behavior) around 850 MPa, while montmorillonite had an anomalously low strength in relation to all the other gouges at 250 MPa. Strength of the saturated samples under drained (low pore pressure) conditions did not correlate with high or low permeability. However, the low permeabilities of these gouges could be a factor in the measured low shear stresses along fault regions if excess pore pressures were created as a result of shearing or compaction, and this pressure was unable to dissipate through a thick section of the material.
J. Geophys. Res., B, Paper 5B1093

Seismology

6940 Phenomena Related to Earthquake Prediction
PROBABILITIES OF OCCURRENCE OF LARGE PLATE RUPTURING EARTHQUAKES FOR THE SAN ANDREAS, SAN JACINTO, AND IMPERIAL FAULTS, CALIFORNIA, 1983-2003
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The San Andreas, San Jacinto and Imperial faults in California are divided into 19 segments; conditional probabilities are calculated that a particular segment will be the site of a large plate rupturing earthquake, i.e., an event that breaks the entire down-dip extent of the seismogenic zone, during the next 20 years. The sizes of such events, which account for most of the slip that occurs seismically, appear to vary greatly for different segments of these faults. Repeat times are estimated from times of historic and pre-historic events, tectonic similarity, and times calculated from co-seismic displacement in the last large shock divided by a rate of fault motion or strain buildup. A 325 km section of the southern San Andreas between Tejon Pass and the Salton Sea has about a 25% chance of rupturing in a shock of magnitude near 8 during the next 20 years. All the other segments have only a small chance (i.e., less than 5 to 10%) of rupturing in an event of magnitude near 8 during that interval. The segment of the San Andreas fault from opposite San Jose to San Juan Bautista, which ruptured less than 1.5 m in 1906 and which probably also broke in 1838, is calculated to have a moderate to high probability of an earthquake of magnitude 6 3/4 to 7 1/4 during the next 20 years.
J. Geophys. Res., B, Paper 4B0400

6950 Seismic Sources
MOMENT-MAGNITUDE RELATIONS IN THEORY AND PRACTICE
Thomas C. Hanks (U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025) and David M. Boore

The observation that motivates this study is the difference in c-values in moment-magnitude relations of the form $\log M_0 = cM_L + d$ between central and southern California. This difference is not at all related to geographical area; rather, it results from positive curvature in the $\log M_0$ - M_L plane and the relatively large number of M_L < 5 earthquakes in the central California data set. With the proscription that the far-field shear waves from which M_L is taken be finite-duration, band-limited, white Gaussian noise in acceleration, we can estimate M_L as a function of M_0 alone, by fixing the $σ_{rms}$ stress drop at 100 bars and f_{max} at 15 Hz. These model calculations fit available California moment-magnitude data for 0 ≲ M_L ≲ 7, 10^{17} ≲ M_0 ≲ 10^{28} dyne-cm with striking accuracy. This range in source strength is entire: earthquakes with M_0 ≥ 10^{28} dyne-cm are unlikely to occur in California, and earthquakes with M_L < 0 cannot be recorded in California, at least under ordinary conditions of recording earthquakes at ordinary hypocentral depths. More fundamentally, the remarkably good fit of model to data implies that the $σ_{rms}$ stress drop of 100 bars (to a factor of two or so) is a stable and pervasive feature of all (M_L ≳ 2½) California earthquakes whose spectral corner frequency lies in the "visible" bandwidth, f_0 ≤ f_{max}.
J. Geophys. Res., B, Paper 4B0432